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THE ISTHMIAN CANAL COMMISSION'S preliminary report, presented to Congress on Dec. 4, recommends the construction of a canal on the Nicaragua route, following substantially the location made by the Walker Commission of 1897-99. The dimensions chosen are a depth at mean low water of 35 ft., a bottom width of 150 ft., and locks 740 × 84 × 35 ft. The estimate of cost is $200,540,000, including in this a double system of locks throughout to permit navigation to continue while a lock is under repair. By dispensing with one set of locks and narrowing the bottom width to 100 ft., the estimate of cost is reduced to $163,913,000. It is estimated that two years would be required for preparatory work, including the formation of a harbor at Greytown, and eight years would be required for building the great dam in the San Juan River, making the total time required for the completion of the canal ten years. The traffic which will use the canal is estimated at 7,030,027 tons in the year 1909. The Panama route is reported to be the only one which can be considered in competition with Nicaragua, and the cost of completing a canal at Panama of the same dimensions as those fixed on for the Nicaragua route is estimated at $142,342,579 or $58,000,000 less than the cost of the Nicaragua route. No method has appeared, however, by which the United States can obtain entire control and ownership of the Panama enterprise, and even if it could do so, there is reason to believe that the price would be such as to make the total cost to the United States not less than the cost of the Nicaragua route. The fact that the Panama route is further from the United States more than offsets the shorter time required for the passage of vessels from ocean to ocean.

A CANAL AT THE DALLES ON THE COLUMBIA River is being advocated in place of the ship-railway, for which an appropriation of $250,000 is already made, and its construction is to be urged before the next Congress by Oregon and Washington representatives. The estimated cost of the canal and locks is about $4,000,000; but the claim is made that the opening of the Columbia River to free navigation is warranted by the rapid growth of agricultural products in Lewiston county, in wheat, fruit, wool and live stock.

THE NEW YORK STATE CANAL BOARD, on Dec. 3, awarded $49,348 to F. J. Dwyer & Co., of Utica, N. Y., on a claim of $57,026, for balance due on their canal contract. This is the first award under the law passed by the last legislature, empowering the Canal Board to settle claims growing out of the suspension of work done under the general canal improvement of 1895.

THE HYDRAULIC DREDGE "SABINE" was launched on Nov. 24 by the Townsend & Downey Shipbuilding & Repair Co., at their new yard at Shooter's Island, off Staten Island, N. Y. This dredge is 150 ft. long, is built to go to sea under her own steam, and is to have a speed of 10 to 12 knots from her twin screws. She is to be put to work on the Sabine Canal, on the Texan coast, and is arranged to carry the dredged material in her own hull.

LAKE COMMERCE, as reported upon by the U. S. Treasury Bureau of Statistics, is making rapid gains. During September last 5,057 vessels entered the 37 principal lake ports; and from Jan. 1 to Oct. 1, the vessel entrances aggregated 28,039. Chicago leads in this list with 1,028 vessels entering in September, and 5,761 during the season, to Oct. 1. The ports of Buffalo, Cleveland and Milwaukee each show a record in excess of 2,000 for the season; and in Detroit, Duluth and Toledo the arrivals ranged from 1,000 to 1,500 for the same period. Up to Oct. 1 the year's tonnage in breadstuffs alone show 47,862,182 bushels of corn carried, 33,331,173 bushels of wheat, and 25,776,512 bushels of oats. Aside from breadstuffs, iron ore, coal and lumber form the great bulk of the traffic. Up to Oct. 1, 2,386,838 tons of unclassified freight were transported on the Lakes. At the one port of Conneaut, O., 353 vessels have unloaded 1,748,255 tons of iron ore this season. Ashtabula alone exceeds this port in ore receipts, with 2,933,647 tons. The Lake lumber trade shows a record of 1,427,000,000 ft. B. M. from Jan. 1 to Oct. 1.

NEW FIREPROOF PIERS AND PIER SHEDS are to be built by the North German Lloyd Steamship Co. to take the place of those destroyed by fire on June 30, 1900. The general plan contemplates the construction of a solid sea wall along the entire front of 900 ft. comprising the property of the company. This sea wall is to be constructed of granite and concrete. On this sea wall or stone bulkhead a substantial building, 850 ft. in length and 130 ft. in width, will be constructed of steel columns, filled with and surrounded by concrete, held in place by iron jackets; brick sides having steel girders, with brick arches as flooring. The second floor will be of the same construction. From the central fireproof bulkhead building there will extend into the river three large piers. The northernmost of these piers will be 730 ft. in length for the present, ultimately to be lengthened to 910 ft; the second, 894 ft., and the third 874 ft. long, the two first 80 ft. and the third 90 ft. wide. The construction of these piers will be of wood piling, protected against fire by a concrete floor on the deck of the pier, covering by planking, and a sheathing of oak on the outside of the pier from below the waterline to the deck of the pier, in order to prevent the possibility of fire attacking the pier underneath. The pier sheds will be constructed of steel columns, filled with and surrounded by concrete, held in place by iron jackets, and of steel trusses.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred on the Mexican Central Ry., near Jimulco, Mexico, on Nov. 30. A passenger train collided head on with a double-header freight, and both trains were completely wrecked. Twelve persons are reported to have been killed, three of whom were Americans. The accident is said to have been due to conflicting train orders.

A SPEED OF 90 MILES PER HOUR was recently made by the Black Diamond Express of the Lehigh Valley R. R. The train consisted of four Pullman cars and an "Atlantic" type engine. This train was 13 mins. late at Rochester Junction, and on the run to Manchester an attempt to make up the lost time was made, and was more than accomplished. On one section of the road a distance of 5.1 miles was made in exactly 3 mins. and 41 secs. For the last 1,800 ft. of that distance brakes were applied, slowing down for a train-order board. The first 4¾ miles, by actual blue-print measurement, were run in 3 mins. and 8 secs. This speed was timed by three watches, which never left the hands of the men holding them. The total distance was covered at an average rate of 88 miles an hour, and the rate for the first 4¾ miles was exactly 90 miles per hour. On the same run the distance between Rochester Junction and Manchester, 20.1 miles, was covered in 19 mins. and 10 secs. This time was taken from a standing start at Rochester Junction to a full stop at Manchester, the speed being reduced to a rate of 25 miles an hour through the Manchester yards.

BIDS FOR WATER FILTER BEDS AT PHILADELphia will be received on Dec. 12. The beds will be located at the lower Roxborough reservoir and comprise the first section of the extensive purification works proposed by the city.

COMPETITIVE PLANS FOR A SEWERAGE SYSTEM at St. Petersburg, Russia, will be received until Aug. 31, 1901, by a municipal commission. There will be prizes of $6,480, $4,100 and $2,100, respectively, for the best three plans.

AN AWARD OF $555,849, on account of alleged rights to a sewerage contract at Havana, Cuba, are reported as awarded to Mr. M J. Dady, of Brooklyn, who had partially entered into a contract before the American occupation of Cuba. An outline of proposed sewerage and paving work at Havana was given in our issue of Nov. 1.

THE SUBWAYS FOR VARIOUS CONDUITS, in connection with the rapid transit tunnel in New York city, are to be abandoned for the present, in accordance with the following resolution, adopted at a recent meeting of the Rapid Transit Commission:

Whereas, no considerable work has been done on the pipe galleries heretofore proposed in the road in Elm St., and

Whereas, the president of the Board of Public Improvements, the Commissioner of Highways and the Commissioner of Water Supply have made various criticisms of the proposed plan, substantially holding that the construction of pipe galleries should await a fuller and completer plan for larger pipe galleries than those which the Board has felt justified in constructing as part of the rapid transit tunnel, and

Whereas, the contractor, John B. McDonald, has requested that he be relieved from the obligation to construct a pipe gallery, and

Whereas, the chief engineer has reported that the various pipes and sub-surface structures now existing can be satisfactorily provided for without the construction of pipe galleries.

Resolved, That the president of the board be requested to withdraw the requisition for pipe galleries.

RUSSIAN TELEPHONE FRANCHISES have been sold at auction, operation to begin Nov. 1, 1901. The government prescribes the conditions of rental, and lets to those offering the lowest yearly rate. The St. Petersburg municipalty agreed to charge 45 roubles annually and obtained the franchise; the former price was 250 roubles per year. The following rates for subscription were accepted for other cities: Odessa, 48 roubles; Rega, 57 roubles; Warsaw, 69 roubles; Moscow, 79 roubles. The prices for restaurants and hotels are 30% higher for a single user, and they are 10 to 20% lower for telephones in general use. The long distance telephone service remains the property of the government.

AN ANTWERP-BRUSSELS ELECTRIC RAILWAY is proposed in a scheme just submitted to the Belgian government by a Brussels banking firm, of which the head is Mr. Ed. Empain. In the City of Brussels, the line would be underground; the road would be 26.6 miles long, and the time of transit would be 23 minutes, equivalent to a speed of 65 miles per hour. The estimated cost of the project is about $10,000,000. The state is to build the line, according to the program laid down.

WORK ON THE GUATEMALA NORTHERN RAILWAY is to be commenced at once by the Central American Improvement Co., New York, in accordance with its recent agreement with the Guatemalan government. The company has entered into a contract to construct 60 miles of railway between El Rancho and Guatemala City, and for this work the company will have the use of the property for ten years. The company is to finance the deal, amounting to about $4,000,000, and at the end of ten years the government has the privilege of buying back the road upon stipulated terms.

THE NEW CONCRETE DAM of the Canadian Electric Co., at Chaudiere Falls, Province of Quebec, was completed on Nov. 7. Within 48 hours after the last batch of concrete was put in place the water was flowing over the dam, and a few hours later there was 4 ft. of water on the crest. Owing to severe rains the river rose over 8 ft. in less than three days. This dam is 824 ft. long, 20 ft. wide on the base and 18 ft. high; the face is built on an ogee curve, and provision is made for raising the water 2 ft. more by means of flash boards. The dam is built entirely of concrete masonry. In ordinary stages the water is allowed to discharge through spillways, pending the completion of the power house and the setting of the turbines, but on Nov. 23, during the flood referred to, the water was 4 ft. 8 ins. over the crest. Messrs. T. Pringle & Sons, of Montreal, are the engineers for the Canadian Electric Co., and Mr. C. H. Hollingsworth is the Resident Engineer. The Engineering Contract Co., of New York and Toronto, built the dam.

THE COMSTOCK MINES in Nevada, which have lately been supplied with electric power, are pumped by means of very large water elevators. Water is forced at a head of 2,500 ft. through two 12½-in. pipes to the nozzles of the elevators, where it is discharged through the 3¼-in. nozzles into the discharge pipes. The total lift is 415 ft. and the outflow is estimated at 4,500 gallons per minute for each elevator.

ACETYLENE GAS is growing in favor in Germany, according to Dr. F. Rose, the British Consul at Stuttgart. He says that in Europe alone over 120,000 HP. is devoted to the manufacture of calcium carbide, and at the present time Germany has 200,000 acetylene gas jets installed. In 1898, 937 patents were taken out on improvements in this connection. German capital is also being invested in its manufacture in Norway and Switzerland and other foreign countries.

SHOT IRON can be economically recovered from the cinder in cupola practice, according to a paper read by Mr. C. H. Putnam, of Moline, Ill., at the recent meeting of the American Foundrymen's Association. The refuse dust and fine cinder coming from the cinder mill is passed through a magnetic separator, consisting of a long iron cylinder wound on the outside with an exciting coil. The use of the iron thus recovered has a tendency to make the castings harder, but by using it in conjunction with moderately soft pig-iron this difficulty is overcome. The amount recovered is said to be sufficient amply to pay for the trouble.

THE GREEN AND GOAT ISLANDS CONCRETE-STEEL BRIDGES AT NIAGARA FALLS, N. Y.

For many years the means of access from the mainland to the picturesque islands which divide the great cataract at Niagara into the so-called "Canadian" and "American" Falls, has been an excessively ugly bow-string truss bridge entirely out of keeping with the scenic beauties of this famous pleasure resort. In anticipation of the prospective large crowds that will undoubtedly flock to Niagara Falls next year, during the period of the Pan-American Exposition at Buffalo, N. Y., it was deemed best by the commissioners of the Niagara Free Park that a new bridge, or rather two new bridges, should be built to connect the mainland with Green Island, and this island with Goat Island. An appeal was made to the state legislature, and an appropriation of sufficient size was made, the state engineer agreeing that a new bridge was necessary. The bridge occupying the site was a four-span iron structure of old-time construction, built in 1855, and had been frequently repaired. It was the third bridge built to connect the mainland with Goat Island, the previous bridges having been built in 1817 and 1818. The 1817 bridge was built by the Porter brothers, who owned the territory all about the Falls, and it was destroyed by the ice in the winter of 1817-1818. When the spring of 1818 opened the Porter brothers selected a site a little further down stream than the site of the first bridge, and this, in fact, is the site on which the bridge of to-day is being built. In the past Green Island has been known as Bath Island, and by this name many who do not reside at Niagara may better locate the site of the present work.

The contract for the new bridge was awarded to W. H. Keepers & Co., of New York, by the Commissioners of the State Reservation. The type of bridge selected was a concrete-steel structure, having a limestone facing. This is a radical departure from the form of bridge that has before occupied the site, but it is more in keeping with the general plan of the landscape artists to beautify the locality all about the great cataract. Important features are brought into the work by the fact that the point of operations is not much over 500 ft. from the brink of the American Fall and extends directly across the upper rapids of the Niagara, where the current is exceedingly swift. In addition to this the nature of the structure to be built requires that the work shall be carried on during the summer and early fall seasons, just when visitors flock to the Falls by the thousands daily. Goat Island is one of the main points of interest and beauty about the state reservation, and, of course, the enjoyment of these thousands must be looked after and access afforded them to Goat Island and the other islands about it. To do this it was found necessary to erect a temporary frame bridge about 6 ft. wide on the lower or Falls side of the bridge to be removed between the mainland and Green Island, while between Green Island and Goat Island a temporary structure has been erected on the up-stream side of the bridge connecting the two islands. These temporary bridges are now constantly patrolled by special officers, whose duty it is to see that the crowds passing along do not loiter at any point on the bridges to watch the operations.

The erection of these temporary bridges, especially the one leading from the mainland to Green Island, was an engineering feat of no small importance in itself. The point of operations was so fraught with elements of danger that even some of the state officials were just a little fearful of accidents, for the current bursts from beneath the old bridge and plunges on to and over the Fall in such a fierce way that a human being once within its grasp would have little hope for life. Still the temporary bridges were erected without accident, and with an ease that was surprising. The method employed was to build cribs and throw them off the old bridge into the current, holding them fast with cables until they were filled with stone and sunk to the river bed. There were 17 cribs placed between the mainland and Green Island, of which number three were 18 × 7 ft. in size; four 12 × 7 ft., four 7 × 9 ft., and six 14 × 8 ft. The largest cribs hold about eight cords of stone and the smallest about two cords. The men employed in placing these cribs worked on a life raft, with life ropes about their waists, and life buoys floated nearby. This feature, together with the nature of the waters over which the bridge is being built, is well portrayed in the accompanying views, Figs. 1 and 2, from photographs. Of course, it was necessary to close all carriage traffic to Goat Island. In order to continue the reservation van service on Goat Island, the manager established a headquarters there with animals and vans, taking over sufficient feed to keep them until regular travel is once more opened.

FIG. 1.—VIEW OF BRIDGE BETWEEN GREEN AND GOAT ISLANDS, NIAGARA FALLS, SHOWING PIER AND FOUNDATION WORK IN PROGRESS.

It is expected that the new concrete arches will be of great architectural beauty, and add much to the appearance of the state reservation at this point. A fairly good idea of their appearance will be gained from Fig. 3, which shows the three-span bridge between the mainland and Green Island and gives plans and sections of one of the arches which show graphically the structural features described further on.

The bridge between the mainland and Green Island will be 371 ft. long, which length includes the finishing panels. It will consist of three spans having rises, respectively, of 10 ft., 11½ ft. and 10 ft. The two end spans will each be 103½ ft. long, while the center span will have a length of 110 ft. The piers of this bridge will be 13½ ft. wide, and have a length of 53 ft. 6 ins. They will be set on a concrete base securely fastened to the rock bottom of the river. The up-stream end of the piers will have a granite nose or ice-breaker. The roadway will be 20 ft. wide in the clear, and on each side of it there will be a walk 9½ ft. wide for pedestrians. There will be an iron railing of appropriate design on the bridge.

The bridge between Green Island and Goat Island will be 198 ft. long. It will have three spans, the rises of which will be 9, 10 and 9 ft. The length of the end spans will be 50½ ft., and the center span will be 55 ft. long. The piers of this bridge will be 8 ft. wide or thick, and they will have a length of 50 ft. 5 ins. These piers will have granite ice-breakers the same as the piers on the larger bridge. The roadway and walks will be similar to those of the bridge from the mainland to Green Island. There will be pilasters over each pier with projecting belt course at the top, on top of which will be placed the coping. There will be cone-shaped protections at the base of the pilasters. The ring stones will run from 18 to 24 ins. in the small bridge to 36 to 42 ins. in the big bridge, and it is provided that they shall extend into the concrete work alternately 10 and 18 ins. Every fifth stone shall be a header, and extend into the work 18 ins. Steel ribs with three-foot centers will be imbedded in the concrete of the arches. Drainage will be provided by wrought-iron pipes built into the concrete and extending from the center of each space over the piers to the soffit of the arch near springing line, and projecting slightly below soffit. The concrete over the piers will be formed so that any water that may seep through the filling above will be drained to the pipes. The space between the spandrel walls is to be filled with sand, earth, cinders or other suitable material, and the roadway on top is to be composed of about a foot of bank gravel. Granitoid sidewalks are to be laid

There are to be two grades of concrete used in the work. For the arches between skewbacks, the proportions are to be one part Portland cement, two parts sand and four parts broken stone or gravel, which shall pass through a 1¼-in. ring, including the total product of the crusher between 1¼-in. and ¼-in. For the foundation abutments, piers and spandrills, the proportion will be one part Portland cement, three parts sand and six parts broken stone or gravel, which shall pass through a 2-in. ring, including the total product of the crusher between 2 ins. and ¼-in. It is provided that in the last-named portions of the structure large stones containing not less than 1½ cu. ft. each, may be placed in the body of the piers and abutments, each stone to be placed on its broadest bed and not nearer than 8 ins. to another stone or to the face of the work.

The stone facing is to cover the entire structure, including the piers and abutments below water, only excepting the intrados of the arches between the ring stones on each face, and that portion of the abutments buried in the banks.

In building, the concrete for the arches will be started simultaneously from both ends of the arch, and be laid in longitudinal sections wide enough to inclose at least two steel ribs. While being built the sections will be held in place by timber forms. In preparing the foundations all loose shale, sand, mud, or other soft material will be removed from the rock-bed of the river, and depressions in the rock filled and leveled up with concrete, in order that the piers and abutments shall have solid footings.

In preparing for the work it was necessary that the contractors carry across to Green Island and

there store a vast amount of material, in the way of sand, broken stone, cement, etc., sufficient for the bridge between Green Island and Goat Island, and also for the island end of the bridge connecting with the mainland. On the mainland and on Green Island high towers have been erected for the operation of a cableway. The span of the cableway is 600 ft., the width about 54 ft., and the maximum height 70 ft. A track on top of the towers makes it possible to run the truck back and forth, and as the carrier travels the full length of the bridge between the mainland and Green Island, material is delivered at the point needed. This cableway will be used for taking out the old bridge and carrying it to shore. Two large derricks will handle the material for the smaller bridge between Green Island and Goat Island.

FIG. 2.—VIEW OF SITE OF GREEN ISLAND BRIDGE, NIAGARA FALLS, SHOWING METHOD OF PLACING STONE-FILLED CRIB PIERS FOR TEMPORARY BRIDGE.

In building the piers a shield will be built, and inside of this a cofferdam will be located, anchorages for this part of the work having been obtained by stretching cables to rocks in the rapids above the work.

Water in the cofferdams will be removed by centrifugal pumps operated by electric motors, and the mixers will also be operated by electric motors. For this service Keepers & Co. have four electric motors on the ground, two of them being of 7½ HP., one 10 HP., and one 25 HP. Every effort will be made to complete the bridges before severe cold weather sets in, and in order to accomplish this arc lights have been placed in order that night shifts may be employed.

At the site of the bridge the current runs at fully 30 miles an hour. The average depth of the water is about 6 ft., the maximum depth being in the neighborhood of 11 ft. Life lines have been run along the piers of the temporary bridge, and below the site of the first cofferdam buoys swing in the current a few feet further down stream. All these precautions are so that should any of the workmen be so unfortunate as to fall from the work into the current, they would have some slight chance of catching either the life lines or the buoys. To pass beyond them down stream would mean death by being swept over the American Fall, and this so quickly that one would hardly be caught by the current before being hurled to death on the talus at the foot of the precipice.

R. S. Buck is consulting engineer on the work, and Mr. D. D. Waldo, of Medina, represents the state engineer. John M. Braly, of New York, is the engineer of W. H. Keepers & Co., and Chas. W. Danforth is his assistant. Charles H. Turver, of Niagara Falls, is superintendent for W. H. Keepers & Co. The appropriation for the bridge is $122,000, and the contract price is $102,070.

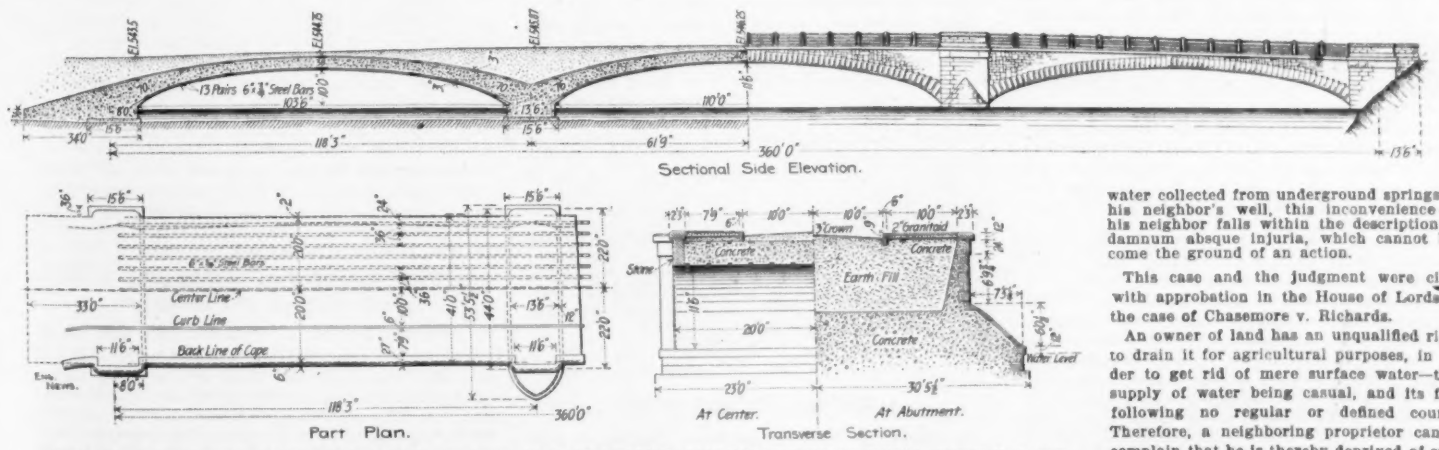

FIG. 3.—PART SIDE ELEVATION AND PLANS AND SECTIONS SHOWING STRUCTURAL DETAILS OF CONCRETE-STEEL BRIDGE, NIAGARA FALLS, N. Y.

R. S. Buck, M. Am. Soc. C. E., Consulting Engineer. W. H. Keepers & Co., New York, N. Y., Contractors.

BRITISH LAW IN REGARD TO UNDERGROUND WATER.*

By J. Shiress Will, Q. C.

The law with regard to the question of ownership in underground water first became definitely settled in the year 1859 by the case of Chasemore v. Richards (7 H. L., cases 349). The plaintiff was the occupier of an ancient mill on the River Wandle, and for more than 60 years he and the preceding occupiers of the mill had used and enjoyed as of right the flow of the river for the purpose of working their mill. The defendant represented the local Board of Health of Croydon, who, for the purposes of supplying the town of Croydon with water, sank a well to the depth of 74 ft. in their own land in the town of Croydon, and about a quarter of a mile from the River Wandle, and pumped up large quantities of water from their well. By means of the well and the pumping the local Board of Health intercepted underground water (but underground water only) that otherwise would have flowed and found its way into the River Wandle, and so to the plaintiff's mill. The quantity so diverted was sufficient to be of sensible value towards the working of the mill. The water was underground water, not flowing in any defined channel, but percolating or oozing through the soil more or less, according to the quantity of rain that might chance to fall. The judgment of the House of Lords was unanimous. They held that the principles which regulate the right of owners of land in respect to water flowing in known and defined channels, whether upon or below the surface of the ground, do not apply to underground water which percolates through the strata in no known channels.

Of the judicial decisions prior to the case of Chasemore v. Richards, it is only necessary to refer to the case of Acton v. Blundell, in 1843. The plaintiff was the owner of a piece of land on which was a cotton mill, in a street called the Wallgate, in the town of Wigan, in which he carried on the business of a cotton spinner. A former owner and occupier of the land and mill had sunk a well, and raised water for the working of the mill. The defendants sank a coal-pit in their own land at about three-quarters of a mile from the plaintiff's well; and about three years after they sank a second pit at a somewhat less distance. The consequence was that by the first pit the supply of water was considerably diminished in the plaintiff's well, and by the second it was rendered altogether insufficient for the purposes of the mill. The judgment of the Exchequer Chamber was delivered by Chief Justice Tindal. It was held the action would not lie. He decided:

> We think the present case is not to be governed by the law which applies to rivers and flowing streams, but that it rather falls within the principle which gives to the owner of the soil all that lies beneath his surface—that the land immediately below is his property, whether it is solid rock or porous ground, venous earth, or part soil, part water; that the person who owns the surface may dig therein and apply all that is there found to his own purposes at his free will and pleasure; and that if, in the exercise of such right, he intercepts or drains off the water collected from underground springs in his neighbor's well, this inconvenience to his neighbor falls within the description of damnum absque injuria, which cannot become the ground of an action.

This case and the judgment were cited with approbation in the House of Lords in the case of Chasemore v. Richards.

An owner of land has an unqualified right to drain it for agricultural purposes, in order to get rid of mere surface water—that supply of water being casual, and its flow following no regular or defined course. Therefore, a neighboring proprietor cannot complain that he is thereby deprived of such water which otherwise would have come to his land.

A landowner has also a right to appropriate surface water which does not flow over his land in any definite channel, although the water is thereby prevented from reaching a watercourse which it previously supplied and which had for more than 50 years worked the plaintiff's mill.

The principles laid down in the case of Chasemore v. Richards have never been shaken or departed from. In every case that has arisen since then, the difficulty has been, not whether the decision in Chasemore v. Richards

*Abstract (from the Iron and Coal Trades Review) of a paper read before the Surveyors' Institution.

was right, but rather in its application to the facts of the particular case. An examination of the more important of the decisions will illustrate this.

The case of the Ballacorkish Silver, Lead & Copper Mining Co. v. Harrison, in 1873, was decided in the Privy Council on appeal from the Court of Chancery in the Isle of Man. The appellants, by a lease from the Crown, were entitled to the minerals under certain lands occupied by the respondents. They sank certain shafts and enlarged others and worked the mines. The damage complained of by the respondents was the withdrawal, by percolation into the mine, of water which it was averred would otherwise flow into, and having flowed into, would have been retained in, the wells or springs on the respondents' land. It appears that a new level had been driven by the appellants under the respondents' land about two years before the litigation, and that from that time the wells and springs were dried up. It does not appear to have been denied that if the litigant parties had been the respective owners of two adjacent closes, and one of them, mining in his own land, had drawn off, by natural percolation through the soil, the water which fed a spring or well on the land of the other, no action would have lain, and that the cases of Acton v. Blundell and Chasemore v. Richards would have governed the matter. It was sought, however, by the respondents, to distinguish that particular case on certain very special grounds: viz., that the appellants represented, through the Crown, the lord of the manor, and that the respondents were customary tenants of the manor; and that the lord, having granted the surface to the customary tenants, could not lawfully derogate from his own grant by so working the mines as to inflict damage of this description upon the tenants. The judgment of the Privy Council was in favor of the appellants in the particular circumstances of the case.

In the case of the Corporation of Bradford v. Pickles, it appeared that the Bradford Corporation derived a supply of water from a large spring known as Many Wells, which issues from the ground 20 or 30 yds. to the east of Doll Lane, and also from a stream to the south of Many Wells, which had its origin in a smaller spring on the respondent's land, close to Doll Lane, at a point known as the Watering Spot, from which the water runs in a definite channel into Trooper Farm. It was an admitted fact in the case that the statutes, to the benefit of whose provisions the Bradford Corporation were now entitled, made no provision for compensating the defendant in the event of any right or interest of his being prejudicially affected. In 1892 the respondent began to sink a shaft on his land adjoining the lane, and to the west of the Many Wells spring, and also to drive a level through his land for the professed purpose of draining the strata with a view to the working of his minerals. These operations had the effect of occasionaly discoloring the water in the spring, and also diminishing to some extent the quantity in it and in the stream coming from the Watering Spot, and it became apparent that, if persevered in, they would result in a considerable and permanent diminution of the water supply obtainable from these sources. The Bradford Corporation sought an injunction to restrain the defendant. The House of Lords, affirming the decision of the Court of Appeal, decided in favor of the defendant.

It will be noted, in passing, that the House of Lords decided in this case—and such a decision was in no way new, for many decisions to the like effect have been given in the past—that if a man has a right to do a particular act, his motive in doing so is immaterial, and cannot render the act unlawful.

It was settled by the decision of the House of Lords in Backhouse v. Bonomi, in 1861, that an owner of land has a right at common law to support from the adjacent and subjacent soil. This right does not depend upon prescription, but is inherent in the property. That being so, the question arose whether an owner of land has any such right at common law to the support of underground water. The Court of Exchequer decided that there was no such common-law right of support; and the Court of Exchequer Chamber, on appeal, affirmed the decision. (See Popplewell v. Hodgkinson, in 1869.) In view of later decisions, it becomes desirable to examine the facts of this case. The defendants had made excavations to a great depth, for the purpose of the foundation for a church about to be erected on wet and spongy land. The consequence was to let down certain cottages of the plaintiff, built about two years previously on adojining land of the same character. Before erecting his cottages, the plaintiff had done nothing with the land, either by draining or otherwise, to make it more suitable to bear the weight of the cottages. By the excavation the plaintiff's land was drained, and it subsided, and the cottages were cracked and injured. The land would have subsided even if no buildings had been erected on it. The judgment of the Court of Exchequer Chamber was deliverd by Lord Chief Justice Cockburn, who said they were all of opinion that the judgment of the court below ought to be affirmed. Though there was no doubt that a man had no right to withdraw from his neighbor the support of adjacent soil, there was nothing at common law to prevent his draining that soil, if for any reason it became necessary or convenient for him to do so.

In an earlier case in the House of Lords—viz., that of Elliot v. The Northeastern Railway Co., in 1863—it had been decided that a railway company which had purchased a piece of land for the construction of their line and a railway bridge were not entitled to the additional support furnished by the water in a drowned mine.

Although you may abstract underground percolating water from your neighbor's land in the way before indicated, an important qualification arises where you cannot do this without taking along with the water soil, such as running silt or sand, if you thereby cause your neighbor's land to subside. This point arose in the case of Jordeson v. Sutton, Southcoates, & Drypool Gas Co. The defendants in this case were a gas company duly authorized to erect gasholders. Under these powers, they proceeded to excavate the land in question for the purpose of erecting a gasholder. In doing so they penetrated a large and extensive stratum of what is called "running silt," consisting of fine sand or silt and stagnant water—the expression "running" merely indicating that if the stratum were cut into the silt would run through the opening made. In draining their excavation the defendants withdrew a large quantity of the running silt from under the plaintiff's land, and thus caused a subsidence of the surface, with consequent structural injury to his houses.

There were two points decided by the Court of Appeal in this case which it is desirable to keep quite distinct for our present purpose. The first point is this: The defendants' Special Act incorporated, as is usual, the Gas Works Clauses Acts, 1847 and 1871. Both of these Acts contain a nuisance clause, provided that "nothing in this or the Special Act contained shall prevent the undertakers from being liable to an indictment for nuisance, or to any other legal proceeding to which they may be liable in consequence of making or supplying gas." The Court of Appeal decided that the works of the defendant constituted a nuisance within the meaning of these Acts, and that "nuisance" included nuisance to private individuals as well as to the public. The second point decided is, however, a more important one for our present occasion. A majority of the three judges (The Master of the Rolls and Lord Justice Rigby) decided that the plaintiff's land was supported, not by a stratum of water, but by a bed of wet sand or running silt; and that as the defendants had caused the subsidence of the plaintiff's lands by withdrawing this support, they had committed an actionable nuisance at common law, entitling the plaintiff to damages.

Lord Justice Vaughan Williams has approved of the decision in Popplewell v. Hodgkinson, and in the course of his judgment said, "it seemed to him that the right of support by water to soil did not depend upon the same considerations as the right of support by soil," and he also said:

> To affirm the right of support is to affirm that no land can be drained, or well or trench dug, without the risk of an action for letting down the surface of neighboring land. I cannot persuade myself that such a right is for the interests of society, or essential to the beneficial ownership of land; and if the right is based upon an implied grant supposed to be made when lands belonging to one proprietor were divided by him between two or more other persons, it seems going very far to invent obligations in respect of unknowable and changing subject-matter like underground water. On the whole, I think that both the decided cases and the reason of the thing negative the right of support by water; and this conclusion is fortified by the absence of any affirmation of such a right in the English authorities and text-books, and by the terms in which the right of support is dealt with in the Roman law.

The Court of Referees in Parliament in dealing with the right of support from underground percolating water, have acted on the principles laid down in Chasemore v. Richards. They have disallowed locus standi where mere underground percolating water is threatened, and they have allowed it in cases where they have been satisfied that there was prima facie evidence of the existence of an underground defined and known channel. Where the supply is in the hands of local authorities, and they derive their water from an artesian well or wells, it sometimes happens that these are threatened by a scheme for sinking another well in the neighborhood. In such cases, local authorities have locus standi to protect their water supply, not on the ground of any right to underground water, but because of the standing order of the House of Commons providing for locus standi where they allege that their district will be injuriously affected.*

*See "Riparian Rights in Underground Water," Eng. News, Aug. 19, 1897, for editorial discussion of this subject, including a review of parliamentary orders in cases affecting the water supplies of Newark and Nottingham, England.—Ed.

A PORTABLE FOLDING FORGE.

The novel portable forge here illustrated was primarily designed for use on shipboard, and especially on battleships, cruisers and other naval vessels. Its convenience and ready portability, however, adapt it to a wide range of uses, and its applicability for field and camp service are so evident, it has been named the Army and Navy Forge. When ready for use—as shown in Fig. 1—the rigid steel plate case provides a commodious hearth, standing about 30 ins. above the ground. To this case are removably attached the gearing, blower, tuyeres and supporting legs, the latter fitting into sockets at the corners of the case and having their lower ends flanged so as to give support. An 8-in. crank and handle operates the blast-wheel of the blower, through a train of four accurately cut gears enclosed in a dust-proof case. The tuyere pipe, connecting the blower with the circular tuyere-plate, has a short drop branch for the collection of ashes. To facilitate the handling of long bars, a section on each side of the case is hinged so that it may be turned down; and the raised cover acts as a wind-guard when the forge is in use.

Fig. 2 shows the several parts packed within the case, leaving additional space for blacksmith or farriers' tools. Fig. 3 shows the forge packed for transportation, and the outside dimensions of this closed case are only 27½ ins. long, 22½ ins. wide by 10 ins. deep, with a total weight of 184 lbs. A hasp for pad locking the case and four handles for lifting complete the outfit. This forge has been designed and placed upon the market by the Buffalo Blower Co., of Buffalo, N. Y., and we are indebted to that company for the photographs from which our illustrations are reproduced. We are informed that the forge is already in extensive use. Besides the sales in this country it is being introduced abroad and is in use in the Japanese Navy.

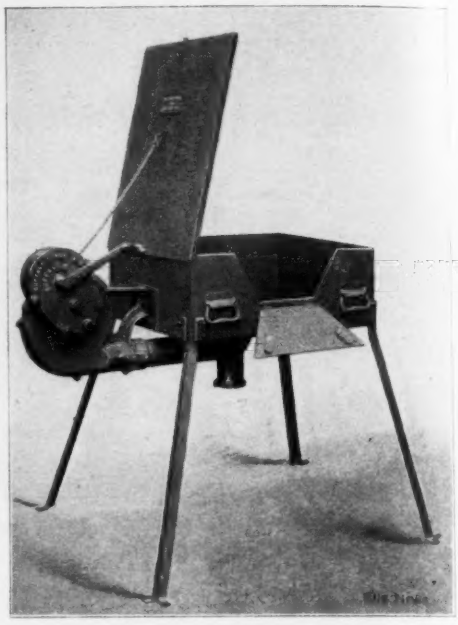

Fig. 1.—Army and Navy Forge; Set up Ready for Use.
Buffalo Forge Co., Buffalo, N. Y., Makers.

It has been recommended for army use by the Quartermaster General of the United States Army, and finds much favor with miners, prospectors, bridge builders, contractors and others.

THE POWER REQUIRED BY CENTRIFUGAL BLOWERS FOR CUPOLAS AND FORGES.*

By William Sangster,† Jun. M. Am. Soc. M. E.

In hardly any other class of machinery is the method of application of so great importance as it is in the case of centrifugal fans. The conditions of one installation are usually so different from those of any other that hard and fast rules are out of the question. The writer, however, offers the following formulas for the power required by centrifugal fans in cupola and forge practice with the hope that they may prove of service when laying out the power plants of shops, etc. They will be found fairly reliable, with the error as a rule on the side of safety.

CUPOLA FANS.—The amount of air required to melt one ton of iron in an ordinary cupola is variously estimated at from 30,000 to 45,000 cu. ft. In order to obtain a safe formula the writer has assumed this value at 40,000 cu. ft. per ton. By ordinary cupolas are meant those which melt up to 6 or 8 tons per hour. Since the pressure of blast increases with the diameter of the cupola, and the

*A paper presented at the New York meeting of the American Society of Mechanical Engineers.
†Boston Blower Co., Hyde Park, Mass.

power required to deliver a given quantity of air increases with this pressure, the formula is expressed in unit terms of 1 ton of iron melted per hour with a blast pressure of 1 oz. per sq. in.

Assuming that a cubic foot of air at atmospheric pressure and at a temperature of 50° F., weighs .078 lbs., we obtain for the height of a column of air corresponding to a pressure of 1 oz. per sq. in.

$$\frac{144}{16 \times .078} = 1{,}154 \text{ ft.}$$

The velocity of air in feet per minute due to that pressure is:

$$V = \sqrt{2\,g\,h.}$$

Substituting their proper values for g and h we have

$$V = 5{,}160 \text{ ft. per minute.}$$

As each ton of iron melted per hour requires 40,000 cu. ft. of air, that is, at the rate of 667 ft. per minute, we

Fig. 2.—Army and Navy Forge; Taken Apart and Put in Case.

shall require as the necessary area of orifice to deliver this amount at 1 oz. pressure,

$$\frac{667 \times 144}{5{,}160} = 18.6 \text{ sq. ins.}$$

The horse-power required will be expressed by the formula:

$$\text{HP.} = \frac{VAP}{16 \times 33{,}000 \times C} \qquad (1)$$

in which V = velocity of the air in feet per minute.
A = area of the orifice in square inches.
P = pressure of the blast in ounces per sq. in.
C = coefficient of efficiency, allowing for friction of belting, air in piping, etc., in this case assumed at 60%.

Substituting the proper values in the above formula we have

$$\text{HP.} = \frac{5{,}160 \times 18.6 \times 1}{16 \times 33{,}000 \times .60} = 0.3.$$

Since the velocity of air varies as the square root of the pressure, and the area of the orifice for a constant quantity varies inversely as the velocity, it follows that the horse-power required to deliver a given quantity of air will vary directly with the pressure, or since VA is a constant, the power will vary directly as the pressure P. To obtain the horse-power required by a cupola fan we may therefore use the following formula:

$$\text{HP.} = 0.3\ TP,$$

in which T = tons of iron melted per hour.
P = pressure of blast in ounces per sq. in.

FORGE FANS.—For ordinary forge fires an allowance of 140 cu. ft. per minute is ample. The usual pressure of blast is about 4 ozs. per sq. in. The velocity of air under this pressure, calling that of 1 oz. 5,160 ft. per minute, will be

$$5{,}160 \times \sqrt{4} = 10{,}320 \text{ ft. per minute.}$$

The area of discharge orifice equals

$$\frac{140 \times 144}{10{,}320} = 1.95 \text{ sq. ins.}$$

The horse-power required (from Equation 1) is

$$\text{HP.} = \frac{10{,}320 \times 1.95 \times 4}{16 \times 33{,}000 \times .60} = 0.25,$$

or a safe allowance is ¼ HP. per forge.

SMOKE EXHAUSTERS.—Modern forge shops are equipped with exhaust systems for removing the smoke and gases from the fires, and delivering the same at some convenient point outside the building. In order to accomplish this result it is necessary to remove a larger quantity of air than is supplied by the blast, and the fan should be run at a low peripheral velocity.

A safe approximation will be to exhaust four times the air supplied by the blast, and to drive the fan at a peripheral velocity corresponding to a pressure of ¾-oz. per sq. in. Since the horse-power required by a fan under constant pressure varies as the quantity of air delivered, and, as the pressure of blast when the quantity is constant, we find that if the fan removes 560 cu. ft. at ¾-oz. pressure we shall require for each forge

$$.25 \times \frac{560}{140} \times \frac{.75}{4} = .19 \text{ HP.,}$$

or a total allowance of .44 HP. per forge.

On account of the diminished first cost some installations have been provided with but one fan for both the blast and the exhaust systems. Such an arrangement is not economical, since a much larger volume of air must be raised to a high pressure than if a separate fan had been used for the exhaust system. In the case given above we should have to handle five times 140 cu. ft. of air at 4-oz. pressure, requiring 1.25 HP. instead of .44 HP. for each forge. Even in a small system the power saved by the extra fan will pay for its cost in less than a year's time.

RELATION OF OUTLET PRESSURE TO OUTLET AREA.—When used as a blower the ratio of outlet to inlet of a centrifugal fan should be so proportioned that air enters the fan with the least possible velocity. Up to a certain area of outlet, varying with the style of fan, the pressure of the outlet remains nearly constant. Beyond this point the pressure gradually drops until the full area of the fan outlet is reached. This drop in pressure is partly caused by the resistance of the air passages of the fan, but more particularly by the vacuum within the fan inlet. This vacuum is necessary to maintain the velocity of the incoming air, and represents a loss in effective pressure as well as in the efficiency of the fan.

This loss increases rapidly with the increased ratio of outlet to inlet areas, and in a fan with equal areas of inlet and outlet about as much work will be expended in drawing the air into the fan as in expelling it.

THE LATEST DECISION AFFECTING UNDERGROUND WATER SUPPLIES, BOROUGH OF BROOKLYN, NEW YORK CITY.

In view of the general importance of the late decision of the New York Court of Appeals regarding rights in underground water, the engineering testimony in the case of Benjamin F. Forbell vs. the City of New York is briefly reviewed below. The decision in question grants damages to a market gardener for the diversion of underground water from his land and enjoins the city from continuing to divert the water.*

The plaintiff owned farming land in the 26th Ward of Brooklyn, within about 2,000 ft. of the Spring Creek pumping station belonging to the water supply plant of the former city of Brooklyn. The plaintiff worked a market garden and claimed that the operation of the driven wells at Spring Creek reduced the natural flow of water in ditches across his land and caused the failure of crops;

Fig. 3.—Army and Navy Forge; Packed Ready for Transportation.

and he sued for damages. There was an average of about 17 ins. of soil on his land, overlying water-bearing sand; and he claimed that before the city wells and pumps were started he could find water anywhere, almost at the surface; and by digging wells from 3 to 8 ft. deep water could be dipped out. Prior to 1882 Spring Creek was a flowing stream, about 8 ft. wide and about 10 ins. deep; this creek dried up in 1883, the first pumping plant having been started in that year; when the pumps stop for a sufficient time, the water returns to the creek. The drying out of the land compelled the plaintiff to abandon the cultivation of water cress, celery and similar plants requiring abundant water.

In answer to the question why his land was not adapted in its present condition for crops which grow on dry and hilly land, he said that it was a failure when planted with tomatoes, peas and beans, owing to lack of sufficient moisture from rainfall; his potato crops were good in quality, but small. His original ditches were supplied by underground springs, and not by surface water.

The first witness for the city was Mr. I. M. de Varona, M. Am. Soc. C. E., engineer of the Brooklyn water supply since Jan. 1, 1898, and familiar with the water supply of Brooklyn since 1882. He described the three pumping plants now at Spring Creek as follows: The first was built in 1882 and opened in September, 1883, and consists of 100 2-in. tube-wells. In 1894 these wells were pulled up, cleaned and redriven to an average depth of 36 ft. below the surface. In 1883 the daily delivery was about 3,330,000 gallons; in 1897 it was about 3,400,000 gallons. The new plant of 1894 included 13 wells, consisting of an outer 6-in casing pipe and an inner suction pipe, 4½ ins. in diameter. The outer pipe was driven 42 to 75 ft. deep, and the suction pipe 30 ft. This plant yielded 4,500,000 gallons daily on its test in 1894. A third deep-well plant was put down in 1896, consisting of six deep wells, driven from 149 to 167 ft.; one of these wells was 6 ins. in diameter. The yield from this group was less than 2,000,000 gallons daily. These three plants were originally operated separately, but since 1898 they can be worked together. Mr. de Varona said that the soil is of alluvial formation, sand and gravel with sometimes a little clay. The ground is saturated below the hydraulic grade line, or slope necessary to force the water to flow to the sea through the ground. Near the pumping station the water level is now from 8 to 14 ft. below the surface, and rises and falls with the pumping. He thought that the heaviest period of pumping may have lowered the water level about 14 ft. He looked upon a driven well plant as a temporary rather than a permanent source of water supply; he considered that the life of wells was measured by the clogging of the strainers by mineral deposits, by the pollution of the supply due to increasing population on the watershed, and by the extension of street paving diverting a portion of the rainfall. He would not rely on such a plant for more than 15 years as an extreme limit. Mr. de Varona said that about eleven square miles of territory would be affected by hard pumping at Spring Creek, with the present driven-wells, yielding in total about 10,000,000 gallons per day. He was not sure that the pumping of that amount would affect land 2,000 ft. from the pumping station, though he admitted that it might.

Mr. John F. Ward, M. Am. Soc. C. E., was called as a witness for the plaintiff, and testified that he had been familiar with water-works construction and operation for between 40 and 50 years, and was connected with the Brooklyn water-works at their beginning. Mr. Ward explained that the effect of pumping at this station was to make a cone-like depression in the general line of the normal water level, the sides of this cone having curved lines growing flatter as they approach the circumference. As the indications point to a fairly clean porous sand, Mr. Ward thought that in the vicinity of the pumping station this cone would have generally regular sides. He explained the source of supply from rainfall, and said that a portion of this water ran off on the surface and another part entered the ground, to be absorbed by vegetation or by the soil. With the soil or sand saturated, all surplus water reaching the line of permanent saturation flows off towards the sea—in Long Island—or towards a creek or pump, assuming by the force of gravity a slope called

*Our issue of Aug. 19, 1897, contained a review of a decision, in a lower court, in a similar Brooklyn case, which case was then pending in the Court of Appeals. The same editorial also reviewed a paper on the subject of underground waters, from a British standpoint, by Mr. Jas. Mansergh, Pres. Inst. C. E. Elsewhere in this issue will be found a detailed historical resume of the "British Law in Regard to Underground Waters," by J. Shiress Will, Q. C., and our editorial columns contain a note on the difference between the British legal decision and that laid down by the highest court of the state of New York.

the water-table, or hydraulic plane. This average slope is about 8 or 10 ft. to the mile, in soil similar to that about Spring Creek. Normally the water planes assume the slope given; pumping alters this slope in the neighborhood of the pumps and lowers it. And if this slope is 11 ft. down, for example, instead of within 1 ft. of the surface, the ground above must be drier.

Mr. Ward further explained that the ordinary well, where there were 20 ft. of soil above the natural water-table, or line of saturation, would obtain the water passing to this table, but would not affect the level of the table so long as the well did not enter it. In other words, the water obtained would be intercepted on its way to the saturated planes, but there is danger in this case of contamination by surface drainage. As to the land in question, the drying out of the soil by evaporation from the surface between the intervals of rainfall is the usual cause of diminished productivity of the soil for agricultural purposes. If this operation of pumping continued long enough it would certainly drain the land to an injurious extent, taken in connection with the natural conditions named above.

Mr. Rudolph Hering, M. Am. Soc. C. E., was the next engineering witness for the city. After giving a synopsis of his long professional career as a hydraulic and civil engineer, Mr. Hering stated that he was very familiar with the territory in question. He stated that since 1892-93 there has been a very considerable increase in building operations as you go eastward from the 26th Ward of Brooklyn. This building and paving over the surface affects the quantity of water that would otherwise reach the saturated plane; the water falling on the streets and houses runs off the surface in large part into the sewers and through these into the creeks or the ocean without passing into the soil.

In describing the normal hydraulic slope of 8 or 10 ft. to the mile, Mr. Hering said that this slope depended upon the amount of rainfall, as the surface of the slope was steeper with a heavy rainfall than with a light one, the greater slope having the greater velocity. He also explained that there were clay strata underlying the sand and gravel on Long Island, and a pipe penetrating this clay stratum may get water from a greater depth; but for how long a time is still a question. At the Spring Creek station the natural flow of the underground water is generally southward; and this holds good for some of the surface water, or that above the water-table, which in a porous soil follows the lines of least resistance. Another large portion sinks vertically until it reaches the water-table, where it stays until it flows by gravity towards the nearest outlet.

As to the rain falling on Mr. Forbell's land, Mr. Hering said that a portion runs off on the surface into natural channels; and the water that stays on the land is in part evaporated when it strikes the soil or the leaves of plants, and another part soaks into the soil and is absorbed by the rootlets of plants to be again evaporated from the plant surface. Another portion of the water remains in the soil by capillary attraction, enabling each particle of matter to hold around it a thin film of water, and hold it in spite of all tendency of gravitation to pull it downward. Any remaining portion of the rainfall passes on down to the water-table. It is this last part that is alone affected by the pumping. As the driven wells extend below the water-table, they cannot draw water from the ground above this table, especially as the soil above contains both air and water and the pumps would soon suck air, destroying their action. Mr. Hering was of the opinion that the lowering of the water-table by pumping or by natural drainage had no effect upon the loss of water in the ground above it by evaporation or by absorption through the roots of plants. As to the cone of depression in the normal water-table, caused by pumping, Mr. Hering explained that by pumping more than the rainfall you can gradually exhaust the supply; and it is usual for engineers, in estimating such a supply, to figure upon the year of least rainfall.

In conclusion Mr. Hering stated that so far as the land in question was concerned he was of the opinion that the lowering of the water-table at Spring Creek, from 2 to 10 ft., was a decided benefit for ordinary farm purposes, because it accomplished the same results as would follow from expensive drainage of the land. He admitted that for plants that must have their roots in water the drained soil was not so good.

Much other testimony was given by experts as to the decreased value of the land for farming purposes, the character of the crops raised on it since pumping began, etc.

In this case Justice Wilmot M. Smith, of the Supreme Court, decided in favor of the plaintiff, Forbell, and awarded him $6,000 damages. The city carried the case to the Court of Appeals, which now sustains the decision of Justice Smith as to damages and also grants a perpetual injunction restraining the city from operating its driven wells at Spring Creek. A large number of similar suits for damages awaited this decision, and more will certainly follow. The court practically decided that if the city wanted water from driven wells it must condemn and buy all the surface land affected. About 49% of the water supply of Brooklyn, it is said, comes from underground sources.

AN AMERICAN CENTRAL-VALVE STEAM ENGINE.*

By E. T. Adams, M. Am. Soc. M. E.†

A hollow piston rod with a valve therein is the essential feature of all central valve engines. The idea of this combination is very old. It was old in this country when Peter Willans took it up in England and made it, literally and figuratively, the central feature of the Willans engine. However, no matter to whom may be due the barren honor of having originated the idea, the brilliant success of Peter Willans made the "central valve" his own, and to him should be accorded the honor pertaining thereto.

Commercially, Willans's success is represented by sales aggregating 320,000 HP., chiefly in units of 100 to 300 HP.; but from an engineering standpoint the measure of his success and the convincing proof of Peter Willan's genius is that he could take this engine, so complex in detail, with its multiplicity of cylinders and its extremely high rotative speed, and actually make it the standard of excellence in the home of the ponderous, slow-going Cornish engine, and among a people so conservative, so opposed to innovation, as our steady-going brethren in Great Britain.

In America, the Willans engine, in spite of its admittedly high record for economy, has been received somewhat coldly. It is manufactured, under license from the English builders, by the Bullock Mfg. Co., of Chicago, and those who knew the late M. C. Bullock, member of this society, can testify that its failure could not be due either to lack of proper enterprise on his part, or to lack of that superfine workmanship which the Willans design makes the sine qua non of the practical operation of the Willans engine.

The engine whose valve gear is here described represents an effort to work up the old central valve idea in a form which shall retain the high economy of the English design, but which shall also meet existing American conditions and conform to safe American practice. This has led to so much that is broadly new, and to combinations so widely different from those adopted by Willans, that the designer feels that the title, "An American Central Valve Engine," is entirely justified.

It seems desirable to divide the description of this engine into two parts: (1) A general statement of the conditions controlling design, with an outline of the essential features of the type of engine which is thereby indicated. (2) A brief description of the valve gear of an American central valve engine.

The conditions to be met are assumed to be the usual conditions existing in small isolated lighting and power installations, as typified, for example, by the power plant of a modern office building, and the accompanying design has been worked out on the theory that the essential features of the engine best adapted to this class of service should be as follows:

MODERATE SPEED, both relative and absolute; that is, any engine should be capable of being operated with safety at a speed 40 to 50% in excess of its rated speed; and for the service here specified the absolute or rated speed should not exceed 200 to 300 revolutions per minute, depending on the size of the unit. The latter condition tends to reduce danger of vibration, while the former tends to lower cost for attendance, depreciation, and repairs, and in a way may be regarded as insurance against careless design, bad workmanship, or too high rating.

A VERTICAL ENGINE, because it requires less floor space, and avoids the tendency of piston and valve to wear down and cause leakage, which is so frequently a source of trouble in horizontal engines. This also involves the proposition that a vertical piston valve, of fixed travel, properly fitted with rings, and working on a seat so designed that "shoulders" cannot be formed, can be made tight initially, and will remain tight, and is by far the most satisfactory and efficient valve, aside from a poppet or a Corliss valve, now in use.

A SINGLE-ACTING ENGINE.—This, if the engine is to be vertical, is enforced by the limited head room usually available. It is desirable in the particular design shown, in that it makes all parts of the engine so readily accessible; but it is perhaps chiefly desirable since it makes it possible to prevent any reversal of stress on the pins and bearings, thus insuring an engine that will run noiseless no matter how severe the service demanded, or how limited the opportunity for adjustment.

A CENTRAL VALVE ENGINE, because it allows simple port opening with very low clearance, because it affords practically perfect drainage of the cylinder at all times, is simple, compact, accessible, and allows the lowest possible number of high-speed moving parts.

A COMPOUND ENGINE, provided that the gain in economy shall justify the expense. Now, the assumed conditions indicate that the engine must be non-condensing, that the load will be variable, that the steam pressure will be low, and that for many months in the year the exhaust can be utilized in the heating system. All these factors are usually urged as indicating the use of a simple engine. It should be noted, however, that the poor showing of non-condensing compound engines under variable load is due very largely to faulty steam distribution. This trouble is not inherent in the type, and can be avoided. At the usual pressure, 80 to 125, now classed as "low," the range in temperature is still very great, and should certainly be divided when possible. How far down the scale of pressures this may profitably be carried is indicated by the gain in economy secured in the so-called "Cornish cycle" by guarding the cylinder from the small drop in temperature corresponding to the difference between the terminal pressure and the back pressure. During the months when the exhaust can be used for heating there will be long periods in spring and fall when the supply from a simple engine will exceed the demand, and it is an unfortunate fact that the periods of maximum demand for heat and maximum demand for power are usually at opposite ends of the day. In the design here presented, the cost of a compound engine will be only slightly greater than the cost of a simple engine, and, as compared with the usual design of simple automatic engine, should require from 30 to 50% less steam, with proportionate decrease in fuel required.

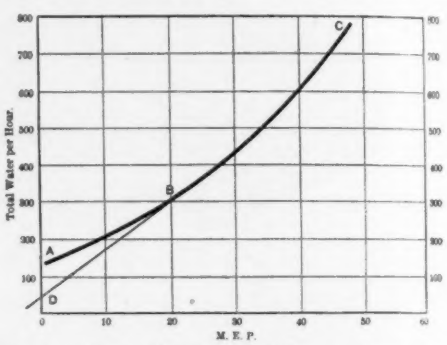

Fig. 1.—Curves Showing Variation in Steam Consumption at Different Loads with Throttling Governor and with Variable Cut-off.

COMBINED THROTTLING AND VARIABLE CUT-OFF.—With variable load, maximum economy will be secured by a combination of throttling control for light loads, and variable cut-off to allow capacity for heavy overload. This is shown very neatly by the accompanying diagram (Fig. 1) adapted from Willans steam-engine trials. The line ABC gives the variation in total water per hour, with variation in load, when the initial pressure is constant and cut-off is varied. The straight line DB gives the variation in total water per hour, with variation in load, with throttling control and a fixed cut-off corresponding to B. Evidently the throttling system gives the better economy for all loads lighter than that corresponding to the point of tangency between the straight line and the curve, and manifestly the ideal plan for the conditions here assumed is variable cut-off from C to B; cut-off becoming stationary at the latter point, and all lighter loads to be met by throttling; the variation in total water per hour under the combined throttling; and automatic system of control being given by the curve DBC, which corresponds to a very moderate variation in water per indicated horse-power for the extreme range of load.

This description of some of the essential features of this engine and the reasons for their adoption leads up to the following brief description of the valve gear and system of regulation.

THE VALVE GEAR.—Fig. 2 is a section taken through the low-pressure cylinder at right angles to the shaft. It

*A paper presented at the New York meeting of the American Society of Mechanical Engineers.

†Assistant to General Superintendent, E. P. Allis Co., Milwaukee, Wis.

is intended to illustrate the action of the valve gear, and does not show the actual construction of the engine as a whole. As shown in the cut, the low-pressure crank is on its upper center, and the main valve is open by the least. The course of the steam at this instant is from the space above the cylinder head down through the hollow piston rod and the ports in the main valve to the upper side of the piston. On the return stroke the valve will open a passage between the two sides of the piston, and the exhaust simply passes from the space above the piston to the space below it. On the low-pressure side the latter is in communication with the exhaust; on the high-pressure side it forms part of the receiver. The main valve is a balanced piston valve, driven by fixed eccentrics on the crank-pin, hence the valve has a motion relative to the hollow piston rod, which is proportional to the throw of the eccentric, and both valve and rod have a motion relative to the frame, proportional to the length of the crank. The former motion controls admission, release, and compression; the latter, as will presently be shown, controls cut-off.

The main valve is designed chiefly with reference to the clearance. In the sketch submitted, the stroke is short and clearance is about 3%. The main valve is designed to release very late in the stroke, and to compress to usual receiver pressure, hence the main valve will have a fixed cut-off at ¾-stroke or later. This, however, is merely a secondary cut-off, a safeguard against leakage through to the exhaust. Cut-off proper takes place at

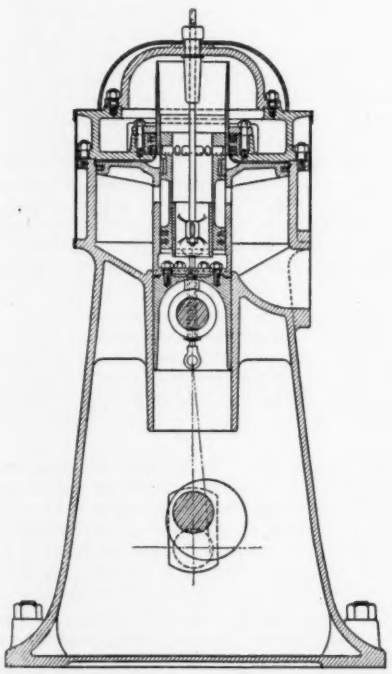

Fig. 2.—Section Through Low-Pressure Cylinder of American Central Valve Engine.

practically full piston speed, when the ports in the main valve run behind the stationary cut-off sleeve, and variation in cut-off is secured by adjusting the height of this sleeve. Evidently the cut-off sleeve has this in common with the ordinary throttle valve. It is stationary when the load is constant, and only needs adjustment when there is a change in load. Hence the two may be controlled by the same regulator, and if they shall be so combined and adjusted that fixed cut-off shall never be earlier, and the throttling action of the valve shall never extend later than that point of cut-off which affords maximum economy, say ¼-stroke, we secure the ideal system of steam distribution for an engine subjected to variable load, with the further practical advantage of a high-speed engine without any high-speed rocker arms and other flying parts in its regulator connections.

As is to be expected in any departure from beaten paths, many interesting problems have arisen in the development of this design, practically all of which have been omitted here, in accordance with the belief that the general engineering propositions laid down at the outset are of more general interest than the details of any particular engine. It is always true that how or by whom any work shall be done is ever of less importance than the result to be attained.

And in brief the result here sought may be called the reconstruction of the simple automatic engine. The time has come when it should be radically changed or should be replaced by something better. In every essential part, save only in regulation, it fails to satisfy the conditions with which it is confronted. Its steam consumption in the cylinder is perhaps moderate enough, but the leakage direct to the exhaust is enormous. Its first cost is perhaps low enough, but its cost at the end of ten years is beyond all reason. In its day it was perhaps good enough, but that day is now past, and the time is ripe for the substitution of a type free from the restrictions imposed by early mistakes, and by the traditions of its past, for a new and better type to meet the new demands of a new century.

THE FAILURE OF THE ELEVATED WOODEN WATER TANK AT CEDAR FALLS, IA.

Through the courtesy of Mr. Chas. F. Loweth, M. Am. Soc. C. E., of St. Paul, Minn., we are enabled to give some particulars of the tank failure at Cedar Falls, Ia., noted briefly in our issue of Nov. 29, 1900. In response to an inquiry from this journal, Mr. Loweth wrote us, on Dec. 2, enclosing letters from the mayor and city attorney of Cedar Falls, giving their accounts of the failure, both addressed to Mr. Loweth, and dated Dec. 1. The letters are as follows:

Sir: There are no extended particulars as to the tank. There were two broken hoops, rusted out, and rotten staves, some of them rotten within 1 in. of the outside. It simply collapsed and fell to the ground. Water committee instructed to investigate as to new tank. Frame all right. No photograph (of the wreck.—Ed.)

Peter Melendy, Mayor.

Sir: Your favor asking about the water tank is at hand. Your supposition was correct that the failure was due to the rusting of the hoops. It is said that for a number of days prior to the collapse one of the hoops was known to be broken and subsequently two of them. The day before the failure, Boehmler, who is the superintendent, said that a hoop was broken, but it was all right as long as the rest held; a very correct proposition. The tank was in good condition so far as leakage was concerned, and had he at once taken out the water and put on new hoops, I have no doubt it would have lasted for years, and as I was informed by a man who lives nearby, a man of intelligence and candor, the staves were sound as though they had been in use but a very few years. The attempt has been made to show the contrary of course to protect the superintendent, but it is not true. He brought a piece of one of the staves down which I saw and said it was rotten. The fact was, it was a stave which had a defective spot and a small part was affected with a rot extending partially through the stave, but of only small extent and one which could have been easily repaired had it caused a leakage. I do not think that for the last year the tank has leaked to any extent whatever for I have noticed repeatedly as I passed and never seen any indication of water. However, it did probably leak more or less, but not extensively, or probably more than it had before. The bottom appears to be all right. The tower structure is uninjured and stands as solid as the first day it was erected. No fault whatever can be ascribed to your plan of the tank or structure. It was simply a failure to take care of it that caused the loss, so upon that score you need not worry yourself, as no reflections whatever have been or can be cast upon your judgment in any respect.

H. C. Hemenway, City Attorney.

The tank was designed by Mr. Loweth, who was engineer for the water-works, and was built in 1888. Mr. Loweth describes the tank and its supports, and comments on the failure, as follows:

The tank was of wood, 20 ft. high, 30 ft. diameter and holding about 90,000 gallons, when full. It rested upon a timber platform on an iron tower 80 ft. high. This tower still stands. The tank was furnished by the Fairbanks, Morse Co., and was of white pine.

As I now remember, the hoops were not painted before erection and so perhaps never got any paint on the sides next the staves in most places. This is, or was, the customary practice. However, for ten years or more past, in the construction of some thirty or so similar structures, I have required the hoops to be painted two coats before putting up. I do not know that this tank has been painted at all since its erection. I remember when seeing it last that it appeared to need painting very badly.

This structure, while perhaps not the first, was at least a pioneer of its kind, namely, a metal tower of four posts, surmounted with a wood or metal tank, and they have largely taken the place of standpipes, which were so much in vogue some time ago. With intelligent care these wood tanks should last 15 to 18 years with safety.

REMARKS ON THE CONSTRUCTION OF DAMS.*

By James Mansergh, Pres. Inst. C. E.

I have not left myself time to speak at any length of alterations in water-works methods since 1878, but I should like to say just a few words about the coming into fashion of the stone dam in impounding reservoir construction. Although Mr. Batemant made many such reservoirs in his time, I believe he never built one with a dam of stone, and I think I am right in saying that the Vyrnwy was the first Mr. Hawksley‡ had to do with. In 1878 I built a small one on the River Wyre, in front of a low weir of Sir Robert Rawlinson's, for the Lancaster Corporation, about 57 ft. high above the river, across a narrow gorge, where I could give the wall a curve in plan of only 100 ft. radius. In such a situation the structure would obviously be made much lighter than, say, the Rankin type section for a long straight wall.

There is great comfort in building a dam in masonry as compared with making an earth bank, but we should not allow fashion to run away with us, and so build in stone when earth and puddle would answer the purpose equally well at much less cost. I think where we get 100 ft. of water behind a dam it ought to be built of stone, but it is essential, in my opinion, that such a structure should be founded on an unyielding base of sound rock from side to side of the valley. With anything less than this there may be unequal settlement, owing to the varying weight of the wall, likely to induce fracture. I do not think it is good work to tie a stone wall into the side of an earth valley.

I cannot say that I much admire the American practice of building a composite dam—i. e., part of its length in earth and part in stone—as they are now doing at the New Croton reservoir of New York (which I saw four years ago), and have previously done in many smaller works. They seem to trust in Providence or good luck over there to an extent we dare not do here. In such cases the core or watertight barrier in the earth bank is not puddle, as we should make it, but a thin stone wall joined on to the end of the true stone dam. I am not sure that such a core may not be made from end to end of an earth dam, if very special precautions are taken by well rolling the bank to ensure that unequal settlement or surging does not take place. I have never yet ventured to try it, but if I do not get nervous as I grow older I may some day.

Mr. Hill's wall across the outlet of Thirlmere (Manchester, Eng., water-works.—Ed.) into St. John's Beck is about 50 ft. high above the stream bed, and is a very picturesque structure. The Vyrnwy dam (Liverpool.—Ed.) is an exceptionally heavy wall, splendidly put together, about 85 ft. high above the river; and the granite wall built across the Meavy on Dartmoor by Mr. Sandeman is about the same height, and is a really handsome piece of masonry. I am proud to have been associated, as consulting engineer, with this work, for it has a special interest in that it completes the scheme initiated by Admiral Drake over 300 years ago for the supply of Plymouth. I have not seen Mr. Deacon's wall, built with Aberthaw lime, near Merthyr, nor Mr. Watson's at Gowthwaite, on the Bradford Nidd scheme, and have only sighted the Swansea Cray reservoir works from the railway.

In mentioning these and the three main dams, varying from 122 ft. to 128 ft. high above ground, and the lower submerged wall I am building on the River Elan (Manchester, Eng., water-works?—Ed.) I have, I think, named nearly all, if not quite all, the masonry dams of any pretensions in this country. The highest of these is 40 ft. lower than the New Croton, which is not erected, as at first intended, at Quaker Bridge, but two miles higher up the valley. I have just received some photographs of this work, which represent the wall as being built in horizontal courses of roughly-squared stones—a method which I do not approve. What we want in such a wall is ample weight and good vertical bonding, and this can be secured by building in stones of from 2 to 6 (long) tons in weight, practically as they come from the quarry, and surrounding them with smaller stones and good concrete, well rammed in so as not to leave any interstices.

We are getting in the Elan walls very nearly 50% of solid blocks to a little more filling, and the whole structures will weigh, when complete, from 157 to 160 lbs. per cu. ft., and will practically be monoliths. In one of them we have built 100 ft. high in two eight-month seasons, and cannot discover, by careful examination or with the level the slightest indication of settlement.

*Extract from the inaugural address before the Institution of Civil Engineers, Nov. 6, 1900.

†Mr. John Frederic Bateman, Pres. Inst. C. E., in 1878.—Ed.

‡Mr. Thos. Hawksley, Pres. Inst. C. E., in 1872.

THE NEED FOR MORE WATER in Brooklyn, N. Y., is very strongly put in a recent report by Mr. Robt. Van Buren, Chief Engineer of the department of water supply, Borough of Brooklyn. The report reviews the long series of failures to carry out the recommendations of the Brooklyn officials, in accordance with plans formulated in 1894-5. With the possibility of a water famine constantly in view, practically the only improvement to the works since consolidation has been a steel chimney costing $6,000, and that was paid for from the revenue from consumers. Mr. Van Buren recommends the use of meters, the securing of legislation to permit the development of water in Suffolk county and the completion of plans for a supply from the Housatonic River; also slow sand filter beds for a small, polluted portion of the old supply, for which mechanical filters were proposed and bids rejected quite recently.

ROLLING A SHEET-METAL SPIRAL has been accomplished by the firm of H. W. Caldwell & Son, of Chicago, manufacturers of screw conveyers. Every engineer who has had to do with the design of machinery or structures in which spiral forms are required, appreciates the difficulty involved in their production. Usually, when formed in sheet metal, they have been built up by stamping disks to form sections of the desired spiral and riveting them together. The firm above named, however, according to "The Iron Trade Review," have designed and built a rolling mill with two conical rolls which forms a perfect and continuous spiral from a rectangular strip at one passage. While the product of this mill is primarily designed for use in the conveyers built by the firm, it seems not unlikely that use for such continuous spirals may be found in many other fields now that they can be produced at a moderate cost.

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ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see page XXI-XXIII. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.

Two dissimilar views of the rights in underground water are presented elsewhere in this issue, one embodying a line of British court decisions from 1843 to date, and the other being a very brief statement of a recent decision of the Court of Appeals of the State of New York. The latter is given in connection with an abstract of the testimony of some of the leading engineering witnesses in the case. Briefly put, British law acknowledges no ownership in underground waters, except those moving in well-defined channels, while New York law sustains the claim for such ownership. These two views of the subject were discussed editorially in our issue of Aug. 19, 1897. As we said at the time:

> No city expects to take the waters of a stream for its use without compensating those whose property rights are thereby injured. As a matter of equity it should be equally ready to make good the results of its action when it drains underground waters.

We also said, in 1897, and still believe, that the importance of these decisions in the Brooklyn water supply area are liable to be over-estimated. It is no easy task to prove the diversion of underground waters. Moreover, the acquisition and segregation of drainage areas which feed public water supplies is becoming more common each year, both in England and America, and it is highly desirable that such a plan should be carried out in the case of underground water supplies in populous or highly-cultivated districts, particularly if it can be proved that the wells are drying up land devoted to market gardening.

It looks as though the city council of St. Louis, Mo., in its failure to allow steps to be taken to provide pure water, was emulating the bad example of Philadelphia, in the days of the "water snake," or of Jersey City, a few years ago, or of New York city, only last year, in the case of the proposed Ramapo contract for an additional supply. However that may be, the council refuses to make appropriations for investigating water purification at St. Louis, notwithstanding the requests of the board of public improvements. In addition, we understand it now advocates a reduction in water rates, instead of the utilization of the surplus revenues for building purification works. In a paper read before the Commercial Club of St. Louis, a few days ago, Mr. Edward Flad, M. Am. Soc. C. E., Water Commissioner of St. Louis, urged that the experiments already spoken of should be started at once, that a filtration plant should be built thereafter, and that meters should be installed "as rapidly as possible, with the view of ultimately having every tap metered." He also favored utilizing surplus revenue for the filtration plant. The last is a detail of local finance which we do not propose to discuss, merely calling attention to its possible bearing upon the crippling of the water-works, so as to make it easier to turn the supply end of the plant over to a private company, in accordance with a rather indefinite offer for a gravity supply, made by private parties, without any previous investigation of the scheme by the city officials. The proposals to experiment with filtration before launching out in an expenditure of several millions for a filtration plant certainly seems reasonable. As to the advisability of filtration, it was recommended more than thirty years ago by the late James Kirkwood, and is more essential to St. Louis now than then, since the river is just as muddy as ever and in more danger of pollution from other sources. Recommendations for meters are always in order, but where a city is facing the problem of both increasing the quantity and improving the quality of its public water supply, waste prevention becomes doubly essential. Metering is the only effective method of preventing waste, besides being the most equitable means of determining what consumers shall be charged for the water they use and waste.

The alleged unduly high price for snow removal in the Brooklyn section of New York, during the coming winter, suggests the question of the advisability of bids by the municipality itself whenever there is danger of a combination among contractors, as is said to have been true in this case. The Brooklyn contract was awarded at the price of 50 cts. per cu. yd., against 26¾ cts. last year and against 36 cts. in Manhattan borough this year. It is said that the conditions in Brooklyn this year are little, if any, different from last year, and that they are, if anything, more favorable to low prices than in Manhattan.

We do not say that snow removal comes under the category of public work that should be bid on by the municipality, particularly in New York, but the incident raises the general question of the advisability of this method of checkmating contractors' combinations. Its success would depend largely upon the honesty and ability of the municipal administration. We do not know to what extent the practice suggested has been adopted in this country, but we believe it has been tried in a few instances with alleged success.

Another problem which worries honest city officials is unbalanced bids. In Jersey City a method has been in use for several years which is said to obviate this. The engineer of the street and water commissioners makes an itemized estimate of the cost of the work in hand and the bidders base their prices on percentages of the various items, making the percentages higher or lower than the estimate, as their judgment or fancy may dictate. Under this plan, unbalanced bids are very easily detected, assuming that the engineer's estimates of quantities are reasonably accurate.

THE DESIGN OF WHEELS.

"The wheel has not unreasonably been claimed to be the greatest of human inventions," said the late A. M. Wellington, in one of his characteristic editorials in this journal, many years ago. One needs only to reflect that practically all transportation by land is now and has been for centuries past dependent on the wheel to perceive the forcefulness of this statement. Without the aid of the wheel, burdens could be carried only on the backs of animals or moved by dragging, and at correspondingly great expenditure of power. Such methods suffice for nomadic tribes. The North American Indians, for example, never had other means of transport than their ponies' backs and their dragging lodge poles, even when they inhabited a level, treeless country, where wheeled vehicles could have been readily used. When the change to a pastoral life was made, however, in the early dawn of civilization, the need was felt of better means of transport. The simple idea of cutting two disks off the end of a round tree-trunk, and thrusting a straight stick through their centers to serve as an axle was doubtless developed independently by many different tribes and races. This may be accepted as the most probable manner in which the first invention of the wheel was made, although the actual facts both as to this and the later development of the built-up wheel are lost in the mists that surround the early development of the race.

The wheel, then, with all its parts—hub, spokes, felloe and tire—was developed long prior to the advent of the engineer. Its organs were fashioned and adapted to their respective work with little idea in the mind of the artisan as to the nature and character of the stresses to be sustained. It represents one of the most remarkable examples extant of the work of evolution as applied to mechanical development. The engineer of to-day may apply his most careful and searching analysis to the structure which uncounted generations of wheelwrights have developed; and when he completes his task he can suggest no improvement upon the wheel they have made so long as it is confined to the duty it was designed to do and has done for so many centuries.

Within recent years, however, a new element has come into the wheel problem, and that is the design of wheels for self-moving vehicles. Builders of traction engines have been struggling with this problem for many years; but their difficulties did not attract much attention; and it was not until the bicycle came to be designed that the new element in the wheel problem came to general notice.

The wood spoke wheel, as ordinarily made for carriages, is wholly unsuited to withstand such strains as would be brought upon it by making it fast on its axle and applying a rotating force to the latter. Such a force sets up bending stresses in all the spokes tending to break them off close to the hub. More important even than this in bicycle design, however, was the problem of making a very light wheel of very large diameter, such as was used on the old high-wheel bicycle or "ordinary," which was the first really successful vehicle for self-propulsion.

The old wooden wheel was unsuited to this for several reasons: First, the "dish" of the wheel had to be sacrificed, and with it a large part of the wheel's strength and stiffness. Second, the very small spokes necessary for lightness in so large a wheel became so long and slender that they were very weak as compression members. Third, the size of felloe and tire necessary to receive wooden spokes made the wheel too heavy.

It was to meet these conditions that the present well-known type of bicycle wheel, with its tension spokes of steel wire, was designed; and it was an admirable adaptation of means to ends. So strong a hold did it take on popular favor, that when the high-wheel was displaced by the "safety," or present type of bicycle, the suspension wheel was retained; and it has been extensively adopted since on light horse-drawn vehicles. Whenever it has been attempted to place any considerable loads on wheels of this class, however, or to use them on rough roads or without the protection of the shock-absorbing pneumatic tire, their weakness has become at once apparent.

Those who have given most study to the motor-vehicle development acknowledge that one of the most important problems to-day is what type of wheel shall be used. The imperfections of existing types are coming to be recognized, and there are few more inviting problems to the inventor than the study of the question how materials can best be fashioned to form a wheel

suited to the demands of the present day. It may be of interest, therefore, to consider some of the conditions that should be borne in mind by those who would solve this problem.

In the first place, it is to be noted that timber suitable for wooden wheel construction is every year becoming more scarce and expensive. American carriages have become noted the world over for their remarkable combination of lightness and strength; but this is in great part due to the stores of hickory which have been available. If we are rightly informed, the stock of straight-grained hickory timber in the United States is rapidly dwindling. Wagon and carriage builders in the North and East have for years been procuring their supplies in the forests of Arkansas. When this is exhausted, what shall take its place? Even if we grant that other supplies will be found and that other woods will be utilized, it still remains reasonably certain that the cost of good wooden wheels is bound to increase; and there is the more incentive, therefore, for those who would develop a metal wheel construction.

The great difficulty which must be surmounted by the successful designer of a metal wheel is the provision of elasticity. It is an easy matter to design a metal wheel which shall sustain a heavy static load, or one which shall move over a smooth surface; but to provide a wheel which shall absorb the shocks due to passing over an obstacle at good speed, and do it without the aid of a pneumatic or rubber tire—in short, to do the work which millions of wooden wheels are daily performing—that is the task which no designer of metal wheels has yet accomplished.

As many of our readers may not understand the manner in which a wooden wheel acts to absorb shock, we reprint herewith the following admirable explanation from a paper before the recent International Automobile Congress*:

By dish is meant the inclination of the spokes to the exterior plane of the rim or of the normal plane, to the center line of the spindle. This dish (in wheels with simple dish) is practically balanced by the "carrossage," the inclination of the spindle to the center line of the axle. It results from this that the lowest spoke of the wheel is very nearly vertical on horizontal ground.

The object of dishing the wheels is to give them more elasticity, and more strength. The dish has the effect of transforming the spokes into just so many springs, rigidly connected to each other, and subjected to bending stresses; it makes of the wheels a conical surface, capable of being slightly deformed in an elastic manner, and which has, therefore, a certain flexibility, which it would not have if the wheel had the form of a plane. In the last case the spokes would work solely under compression, and successively, in such a manner, that all elasticity disappears. For wheels, elasticity is one of the most important features; they are continually subjected to violent shocks from the ground and from the axle. If they were of a single piece, and devoid of elasticity the shocks would deform them little by little, and would finish by destroying them entirely, while, if the shocks are divided over several pieces, possessing a certain flexibility, their destructive effect is considerably reduced. As the points struck may give a certain amount under the influence of the speed impressed by the body causing the shock, the pressure at any moment is much feebler than it would be in the case of a shock against a non-elastic body, and its effects are much attenuated. On the contrary, in a non-elastic roller in a single piece, the diameter of the box increases rapidly as a result of these same shocks, and the box is rapidly rendered useless. From what we have said, it follows that absolutely rigid wheels are not very suitable for vehicles intended to run at fast speeds. Thus it has also been found that wood wheels with double dish (double rows of spokes, as in bicycle wheels), good for heavy transport vehicles, which are drawn at a walk on smooth roads, get very rapidly out of shape, if employed on vehicles drawn at a trot, and on slightly rough roads. It has been the same with wheels of two rows of spokes all inclined in the same direction, but with a different dish for the two sets, which the English employed at the beginning of the century, and which gave them bad results. None of these wheels are applicable to automobiles, except if they are provided with elastic tires, and preferably pneumatic tires.

We might make an exception, however, of the metallic wheels constructed and assembled like wooden wheels, and which have, consequently, a certain elasticity, if these wheels did not have other disadvantages from the standpoint of their use on automobiles.

The dish which gives the wheels their elasticity, which is really an indispensable quality, also gives them the strength necessary for transportation on rough roads. The conical form which the dish gives to the assemblage of the spokes, solidarizes them, one with another, and forces them to work together, which they would not do if they were in the same plane. On the other hand, this same conical form is the cause that the different parts always work in the same direction, the same face of a spoke resting always on the same face of the hub, and on the same face of the rim, the pressure being always in the same direction. Contrarily, nothing is more unfavorable to the conservation of the wheels than having to undergo strains which come alternately from the two opposite directions, which would be the case with a flat wheel. The hub can in no case pass from the inside to the outside of the wheel. It results from this, that if the vehicle receives a lateral shock, or runs on a ground inclined in the direction of the axles, one of the wheels is always working in a direction in which it is impossible for it to give. Under these circumstances, two flat wheels have less strength than the one dished wheel which works in the direction favorable to strength, as both offer but small resistance to lateral forces which tend to force the hubs outwardly.

*From the "Horseless Age," Nov. 14.

The correctness of the above statement as to the elasticity produced by the dish of a wooden wheel can be tested by any one. Take hold of a carriage wheel and push vigorously against its rim or strike it a blow. It will yield like a very stiff spring. The solid wheel has no such elasticity, and must be protected by a yielding tire or it will be pounded to pieces. Perhaps it may be said that the tire is to be relied on for elasticity in the wheel of the future; but this again seems doubtful. The pneumatic tire is a success for bicycles and light pleasure vehicles; but it is a most expensive adjunct both in first cost and cost of maintenance. It is a good deal of a nuisance, being the most fruitful source of breakdowns wherever it is used, and for heavy vehicles it is quite out of the question. Another prominent disadvantage of the pneumatic tire is that it tends to limit the diameter of the wheels. It is, indeed, more difficult anyway to design a successful metal wheel of large-diameter than one of small diameter; yet there is and will continue to be a demand for good-sized wheels. Even in pleasure vehicles there are some reasons for raising the body of the vehicle out of the dust of the roadway; and when it comes to moving a vehicle over rough roads or over soft roads covered with mud or sand, the large wheels have an advantage which should not be forgotten.

As pointed out above, the tension spoke wheel naturally suggests itself when the design of large wheels is attempted; and it may be worth while to explain the causes of the weakness of tension spoke wheels, to which allusion has already been made. In the ordinary wooden wheel, the spokes are all under compression, and the weight on the axle is carried straight down to the ground by that spoke which is vertically beneath the hub. In the tension spoke wheel, of which the bicycle wheel is a familiar example, the weight on the axle is carried to the top of the wheel and has to be transmitted all the way around the rim to the point diametrically opposite, where the rim is supported by the ground. The stresses in the rim may be likened to those in two very slender semicircular arches, which are held from deformation by the pull of spokes. The fact that the rim and not the spokes is the weak part of the tension spoke wheel was hardly realized in the early days of bicycle manufacture, and it was not until the failure of the light steel rim used on some of the early wheels that the stiffer and heavier wooden rim, with its greater resilience to absorb shocks, was substituted in its place.

From the above analysis, it will be seen at once how the difficulties thicken in the way of securing sufficient strength of rim, as the diameter of a tension spoke wheel is increased. In fact, the rim soon becomes so large as to make the wheel unsightly, and even then it is notably deficient in strength and elasticity to resist shocks due to passage over obstacles, and the lateral stresses which every four-wheeled vehicle imparts to its supports, but which are entirely absent in the bicycle.

So far as can be seen, then, compression spokes must be a feature of a successful wheel for motor vehicles. If they can transmit tension as well, so much the better, or possibly a combination of tension spokes with them may be advantageous. The wheel, with purely tension spokes, however, is so inherently defective that it ought to be discarded by motor-vehicle builders, and in fact has already been discarded in many instances.

We have alluded above to the necessity of making the wheel itself sufficiently elastic to absorb without injury the shocks and jars of rough and rapid service. It is doubtless here that designers of metal wheels for motor-vehicle service will meet their chief difficulty. The quality desired is resilience—the power of absorbing shock. It has been pointed out in these columns that modern methods of testing materials are deficient in that no accurate method of determining elastic resilience, or the inch-pounds of work per cubic inch of volume that different materials can absorb, has ever been introduced. It is to be hoped that some of the new tension impact testing machines which have recently been developed in this country may successfully solve this problem and give to engineering designers more accurate knowledge concerning this important property of the materials used in construction.

At present it can only be said that hickory has probably considerably more elastic resilience per pound of weight than the best steel. The metal wheel designer, therefore, must seek to compensate for this defect in his material by making the different parts of his wheel work together more perfectly to absorb shock than can be done in the wooden wheel, with its more or less imperfect connections.

Again, we would not be understood as claiming that the metal wheel alone is the wheel of the future. Something may well be accomplished, and indeed has been accomplished, in wheels of composite construction. If hickory fails, other woods, even though they be less satisfactory, may be made to take its place. Other materials may perhaps also be utilized; in fact, the whole field is open to the inventive designer.

That it is not an entirely unworked field may be seen from the fact that in the U. S. Patent Office the subclasses of "Wheels" and "Spring Wheels," in the class of "Carriages and Wagons," contain nearly 800 patents, while an equal or greater number are in existence relating to wheels for railway rolling stock. Yet, notwithstanding the work of these prior inventors, there is still room for the design of a better and more satisfactory wheel than any yet developed.

LETTERS TO THE EDITOR.

An Empirical Rule for Strength of I-Beams.

Sir: I have frequently had occasion to know the strength of I-beams when a handbook was not accessible, especially in construction work. This want has led me to work out the following empirical formula, which I present to those whom it may concern:

$$\text{Safe load in tons, uniformly distributed} = \frac{(\text{Depth in inches})^2 \times (\text{depth})^{\frac{1}{2}}}{\text{Span in inches}} \times 7.$$

Expressed in words this is: The depth squared times the cube root of the depth, divided by the span, all in inches, and multiplied by the constant 7. This is the same, but a less cumbersome expression than the $^5/_2$ power of the depth. This formula is only applicable to the lightest section rolled for any particular depth of beam, and it is easily worked out with the slide-rule. Yours truly,

R. D. Johnson, M. E., Resident Engineer.
Shawinigan Water & Power Co.
Shawinigan Falls, P. Q., Nov. 28, 1900.

Higher and Lower Mathematics for the Engineer.

Sir: I quite agree with Professor Ambler in his excellent letter in your issue of Nov. 22, that a "practical working knowledge of the Differential and Integral Calculus is necessary or at least very desirable for the accomplished engineer." My contention is, that this is precisely the kind of knowledge of the science which, as a student, he most distinctly and emphatically does not get. After going through a complete course of calculus at college he is unable to make the least practical use of his knowledge, as he finds to his cost when he takes up applied mechanics. He is obliged to begin at the beginning again, and need go no further than the beginning, because it is only the most elementary part of the science that it is possible to introduce advantageously into applied mechanics, and it is rather difficult to do even that, because algebraic methods are generally simpler. Still, he ought to know how to use the calculus in the simple cases to which it applies, particularly as it will occasionally furnish him with an

excellent test of the accuracy of his algebraic work. For instance, it is well for him to know that he can calculate the horizontal stress in a loaded beam at any given point by simply integrating the vertical stress at that point. It may also be helpful, if he knows how to find the point of maximum horizontal stress in any loaded beam, by calculus methods. Also, if in doubt as to the position of the center of hydrostatic pressure against a triangular surface standing with its base upward, he should be able to convince himself that it is at $\frac{h}{2}$, by means of calculus. But these and many similar and occasionally useful applications involve only so much of calculus as might be taught to an intelligent algebraist in a couple of lessons. It is less calculus and more applications that the student needs. A very few lessons would suffice to impart all the calculus that can be advantageously used in applied mechanics, and if immediately nailed with examples and applications it could truly be said that a "practical working knowledge" of calculus had been acquired. As regards what, upon the whole, is the most useful part of the science to the engineer, namely, Maxima and Minima, I doubt if there is a single practical, concrete case in which there is the least doubt either as to whether there is a maximum or a minimum value, or which of the two it is that we get by equating the differential to zero. The tedious work of testing abstract symbols for maximum and minimum values might well lead the student to suppose that all this has to be gone through with in numerical examples. To express my meaning symbolically, I would say that I think too much time is devoted at school to the X, Y, Z of the science, and not enough to the A, B, C.

Let no word of mine, however, be construed as minimizing the value of mathematics and mechanics to the engineer. They lie at the very base of all scientific engineering. The scientific design of any structure, that which distinguishes it from rule of thumb work, is the determining of the section of equal and sufficient resistance, first in its main features and secondly in each and all of its parts. (Vide the "Wonderful One-horse Shay.") A thorough familiarity with the theory of moments and of the resolution of forces is necessary for this, but always in their simpler forms, because our work lies in the plane of the paper on which it is drawn. Occasionally, we may get a little aid from calculus. For instance, if once in a lifetime we wished to calculate the section of equal resistance of a high masonry wall sustaining only its own weight, it perhaps would be neater to show, by calculus, that it is formed by two logarithmic curves set back to back than to work it out algebraically. But to do so, one should have his elementary calculus at his finger ends, and if, in addition to this, his head is entirely free from the fogs of involutes and evolutes, witches of agnesi and cissoids of diocles, so much the better.

What is an engineer, anyway? Is he one who earns his living by solving intricate problems in acoustics, optics and thermodynamics? Scarcely. His business, that for which he receives pecuniary recompense, is to locate and construct, on an economic basis, lines of railroads, canals, aqueducts, viaducts, sewers and pipes; to build tunnels, piers, docks and dams, etc., and to install plants. Of course he cannot be taught how to do these things at school, but he can be prepared there for beginning the career which has such work as its alluring goal. He can be made an expert instrument man, a good draftsman and a quick and ready computer of all current engineering calculations. By "good draftsman" I mean one who can without loss of time embody in a drawing accurately made to scale, any idea or design of which a figured sketch is given him; who can himself sketch rapidly and correctly, and who can disentangle and plot confused transit notes. By "current engineering calculations" I mean, among others, all such as pertain to surveying and location —plain trigonometry in short—and to mensuration. He should also be thoroughly taught the calculation pertaining to the statics of solid bodies and simple framed structures in order to prepare him for constructional work. I see that I have enumerated, without intending it, most of the qualifications in which the average technical graduate is deficient, at least as to that perfect familiarity and ease and certainty of application which comes only from long practice, and which can be acquired at school, better than picked up afterwards. He should have a good elementary knowledge of steam and the steam engine and water motors. It is far more important that he should be able to set up and run a double-drum hoisting engine or a steam pump, than that he should have pursued a lengthy course of thermodynamics. Newton's second law of motion, and the principle of virtual velocities as enunciated by Descartes—"what is gained in force is lost in velocity"—should be so thoroughly rubbed in during the student's college course as to become mental instincts in all their wide engineering applications.

I have been alluding here more particularly to the proper education, as I understand it, of the civil engineer, but the above indicates, in imperfect outline, it is true, a good preparatory equipment for any branch. A young man thoroughly drilled as above (really thoroughly, you understand) and being besides active, industrious, ambitious and honorable should be worth, on graduation, from $75 to $125 per month.

Perhaps our technical schools do not aim at this. Perhaps we are all "talking through our hats," and these institutions may be primarily schools of science, and only incidentally of engineering. I can understand perfectly that there is a high and useful place which such schools might fill. In this case, my criticism would be that they err in the other extreme of introducing too much practical work. Actually, it seems to me that they occupy too neutral a position between the two extremes. Perhaps later, there may be more specialization, and we may then see the bold and startling innovation of an engineering school where real, sure-enough engineering is actually taught.

E. Sherman Gould.

Yonkers, N. Y., Nov. 26, 1900.

Notes and Queries.

In a note regarding competitive plans for water power development, on p. 365 of our last issue, Christiania was by inadvertence placed in Sweden instead of Norway, and was incorrectly spelled.

E. D. C., St. Paul, Minn., asks whether gas or coal tar mixed with lime makes a desirable paint for roofs of corrugated iron, how long it lasts, how much lime is required to neutralize the acids in the tar, and any other practical pointers in regard to the use of such a paint. We shall be pleased to hear from any of our readers who can give the desired information.

In the review of "Winslow's Tables," published in our issue of Nov. 15, the price of the book was incorrectly given as $1.00, instead of $2.00, which is the actual price.

MINERAL PRODUCTS OF THE UNITED STATES, 1890 TO 1899.

The U. S. Geological Survey, through David T. Day, Chief of Division of Mining and Mineral Resources, has issued its annual statement of the mineral products of the United States for the calendar years 1890 to 1899, inclusive. The growth in the decade, in volume and value, is shown as follows for the principal items:

	Metallic.			
	1890.		1899.	
Product.	Quantity.	Value. $	Quantity.	Value. $
Pig-iron, tons	9,202,703	151,200,410	13,620,703	245,172,624
Silver, T.ozs.	54,500,000	70,464,645	54,764,500	70,806,626
Gold, Troy ozs	1,588,880	32,845,000	3,437,210	71,053,400
Copper,* lbs.	265,115,133	30,848,797	585,342,124	104,190,898
Lead,* tons..	143,630	12,668,166	209,240	18,831,600
Zinc,* tons..	63,683	6,266,407	119,408	13,731,920
Alumin'm, lbs	61,281	61,281	5,200,000	1,716,000
	Non-metallic.			
Coal:				
Bit., tons..	111,320,016	110,420,801	193,321,987	167,935,340
Anth., tons.	41,489,858	66,383,772	53,944,647	88,142,130
Natural gas.,	.....	18,742,725	.....	20,024,873
Petrol., bbls..	45,822,672	35,365,105	57,070,850	64,603,904
Brick clay...	.....	8,500,000	.....	11,250,000
Cement, bbls.	8,000,000	6,000,000	14,311,407	14,417,658
Stone	.....	47,000,000	.....	44,736,576

*At New York. Pig-iron and Penn. anthracite coal are given in long tons, and lead, zinc, and bituminous coal in short tons.

A practically corresponding increase in output and value is shown in the minor non-metallic products, including abrasive materials, chemical materials, pigments and miscellaneous. The total values of these products, at about 2-year periods, is given as follows:

	Totals.			
Year.	Metallic.	Non-metallic.	Unspecified estimated.	Grand total.
1890.....	$305,735,670	$312,776,503	$1,000,000	$619,512,173
1892.....	307,716,239	339,958,842	1,000,000	648,675,081
1894.....	218,168,788	307,455,351	1,000,000	526,624,139
1896.....	287,596,906	333,936,110	1,000,000	622,533,016
1898.....	343,400,955	353,419,765	1,000,000	697,820,720
1899.....	527,218,084	447,790,862	1,000,000	976,008,946

In 1880, the total value of all metallic, non-metallic and unspecified products was $369,319,000 for the United States.

A COMPETITIVE TEST OF FIELD ORDNANCE is ordered by the Ordnance Bureau of the War Department, to commence March 20, 1901. The purpose is to select a gun for the U. S. artillery that will bring this branch up to the standard of foreign field artillery.

NAVAL CONTRACTS for eleven armored ships, to cost about $66,000,000 complete, are to be awarded on Dec. 7. The hulls and machinery alone will cost $42,000,000 for the five battleships and six armored cruisers authorized by Congress on March 3, 1899, and June 7, 1900.

STEEL TIES are being tried experimentally on the Lake Shore & Michigan Southern Ry., which has ordered 1,500 ties of a pattern invented by Mr. C. Buhrer, of Sandusky, O., who is one of the roadmasters. The ties are made from old rails, rerolled to form an I-beam section, 5 ins. wide over the upper flange, 8 ins. wide over the lower flange, and 3 ins. deep. The head and upper part of the web of the rail are rolled out to form the lower flange. The rails are attached by bolted clamps. The weight is about 185 lbs. per tie, which is more liberal and more near the requirements, as shown by foreign experience, than the weight of most steel ties that have been tried in this country. The idea is for railways to utilize their old rails in this way, and to introduce the steel ties gradually in tie renewals. The ties can also be rolled from blooms in the usual way.

THE PEARY ARCTIC EXPEDITION, according to letters from Lieut. Peary brought by the Stein party, is doing well. Lieut. Peary, Dr. Dedrick and Matt. Henson were all well last spring, when the letters were written. The party wintered at Etah, but started north last March in its search for the North Pole, and reached Greely's old camp at Fort Conger, about 260 miles north of Etah, in 24 days. Peary's route to this point was along the channel, about 340 miles long, leading from the south entrance of Smith's Sound to Cape Brevoort, on the Lincoln Sea. He proposed to leave Dr. Dedrich and some of the natives at Fort Conger, and start north with Henson and his best Esquimaux. His movements, according to a letter of August, 1899, to the Peary Arctic Club, would depend upon the conditions found. He might cross the channel and follow up the North Greenland coast to its terminal; or, follow the west side of the channel to Cape Heela and there strike northward across the sea-ice. His latest letter shows that he has decided to cross to the Greenland coast, following practically the Lockwood route to the north. Fort Conger is about 550 miles from the North Pole.

THE LATEST SOUNDINGS AT THE BREAK IN THE AUSTIN DAM.

By Thomas U. Taylor, Assoc. M. Am. Soc. C. E.*

Upon the present condition of the foundation of that part of the Austin dam that was broken out hinges the proper interpretation of the cause of its failure. So important was this special feature that the writer has, on four distinct occasions, sounded in that part of the broken section through which the water at present flows. The first of these soundings was reported in the issue of the Engineering News, of June 14, 1900. On Oct 13, an exhaustive and complete line of soundings was made across the present current (which is confined between stations 280 and 583, measuring from the east bulkhead) in the line of the upper face. The soundings were made 20 ft. apart and in no case did the sounding-rod strike solid rock at a less distance than 9.5 ft. below the datum of the "low water" level, which was the zero of reference in all elevations in the construction and was the top of the toe of the dam.

On Oct. 29, a fuller and more complete set of soundings was made. Three lines of soundings (marked X, Y and Z, Fig. 1), parallel to the upper face of dam, were made at distances of 0.0, 16.5 and 42 ft., respectively, from the upper face. A cord was tagged every 20 ft., and the soundings were made with a sharpened ¾-in. iron rod from a boat held in position by the tagged cord and by a guy rope in the hands of assistants on the shore line north of the dam. Table I. shows the result of the soundings, where the depth is measured from the toe of the dam, the historic "low water" level. At the time of soundings the water level was 56.1 ft. below the crest of the dam.

TABLE I.—Soundings at Site of Wrecked Portion of Austin Dam, Made Oct. 29, 1900.

Distance.	Line X. Depth.	Line X. Bottom.	Line Y. Depth.	Line Y. Bottom.	Line Z. Depth.	Line Z. Bottom.
700 ft.	10.9 ft.	.....	....	.....	....	.....
650 "	12.0 "	.....	....	.....	....	.....
600 "	13.0 "	.....	....	.....	....	.....
583 "	13.0 "	.....	....	.....	....	.....
570 "	13.3 "	Rock.	9.1 ft.	Rock.	9.5 ft.	Rock.
550 "	9.5 "	"	9.1 "	"	10.1 "	"
530 "	9.9 "	"	10.1 "	"	10.9 "	"
510 "	10.6 "	"	11.1 "	"	11.3 "	"
500 "	10.9 "	"	11.8 "	"	11.9 "	"
490 "	11.1 "	"	12.6 "	"	12.5 "	"
470 "	12.3 "	"	12.6 "	"	12.4 "	"
450 "	12.6C"	"	12.9 "	"	12.6 "	"
430 "	12.3C"	"	13.1 "	"	13.5 "	"
410 "	11.9C"	"	12.1 "	"	13.1 "	"
400 "	11.6C"	"	11.6 "	"	12.2 "	"
390 "	11.3C"	"	11.1 "	"	11.3 "	Sand.
370 "	10.9C"	"	9.1 "	"	11.0 "	Rock.
350 "	8.1C"	"	8.9 "	"	9.6 "	Mud.
340 "	....	Sand.	7.1 "	Mud.	7.9 "	Gravel.
320 "	....	Sand.	....	Gravel.	....	.....
300 "	....	Sand.	....	.....	....	.....

Depths marked "C" indicate that sand was lying on the rock and that the sounding-rod was forced through the sand to the solid rock.

On Nov. 14, another line of soundings marked "Line T," Fig. 1, 60 ft. from the upper face, and

*Professor of Civil Engineering, University of Texas, Austin, Tex.

therefore, 6 ft. under the toe of the dam, was made with the following results: Depth to rock at Sta. 550, 12 ft.; Sta. 500, 14 ft.; Sta. 450, 14 ft.; Sta. 400, 15 ft.; Sta. 350, 15 ft. to sand.

If we remember that the height of the top of the toe of the dam above the rocky bed of the river was 6 ft., and that the foundation was not (with the exception of the trenches) over 8 ft. below "low water," a glance at the above table will convince any one that there is no part of the foundation in the western 300 ft. of the broken section remaining. From the present ordinary eastern water edge a large sand bank extends to the end of the west end of the eastern standing section, covering 140 ft. of the former bed of the dam. Soundings were not made through this sand bank, but the crest of the big section of dam shown in all the views of the broken part is on an average only 4 ft. lower than the crest of the standing dam, which indicates very clearly that its foundation went with it, as it is resting practically in the old tail race, whose bed was lower than the bed of dam.

In all 74 soundings were made and 67 of these show that the depth of present rock is over 8 ft. below "low water," and at the other 7 soundings we could not drive the rod through the sand, mud or gravel, to solid rock. At no place was any solid rock encountered as near as 8 ft. to the "low water" mark in the area of soundings, which covered a space of 18,000 sq. ft.

The soundings in Line X, at Stations 583, 600, 650 and 700, were made by letting the boat slide along by the face of the western sounding section from Q to C.

Fig. 1 represents the plan and elevation of the present dam, where the vertical scale is magnified ten times. The rock bottom shown in elevation is a profile along the line Q C U V M A H. The line Y was taken in preference to X in order to get away from any possibility of sounding in any part of the trenches that were placed under the upper face.

After a great deal of time and trouble, I succeeded in finding among the city records the old cross-sections of the dam foundation at Stations 300, 350, 400, 450, 500 and 550—that part of the dam covered by my lines of soundings. These profiles are shown in Fig. 2, by the dotted line, while the present bottom of the river is marked at its proper distance below the old foundation bed and is indicated by rock shading.

The minimum, maximum and average, and depths along the Y sounding line are shown by Table II.:

TABLE II.—Depths of Foundations, Original Cross-sections, Compared with Soundings on Line Y.

Station.	On original cross-section lines. Minimum.	Maximum.	Average.	Longitudinally on line Y.
300	6.6	7.2	6.9	6.7
350	7.0	8.6*	7.3	7.3
400	7.4	8.5	7.8	7.5
450	7.2	8.4	7.9	7.8
500	7.2	8.1	7.8	7.2
550	6.7	7.4	7.1	7.2

*In small "V"-shaped depression about 10 ft. wide, 1.5-ft. maximum depth below ordinary average rock surface in vicinity.

The facts that these cross-sections were taken 50 ft. apart, by the engineers in charge of construction, and that the depths vary so slightly, indicate that the original rock bottom was almost horizontal, both longitudinally and transversely.

The condition of the foundation, the detached standing section B D, Fig. 1, and the condition and position of the other broken section (which disappeared soon after the break—Ed.), all preclude the theory advanced by one interpreter that the dam broke at the level where it was 31 ft. in thickness. This level was 25 ft. above "low water" and 35 ft. below the crest. If it broke on this level then there was a section only 35 ft. high that broke off and moved back. The broken sections moved down the stream about 60 to 70 ft., and rested in a position practically parallel to the original positions, and in the tail race of the dam, the bottom of which was lower (except at the narrow neck opposite Sta. 550) than the foundation of the dam.

If the dam had broken at the level of 25 ft. above "low water," then when the upper 35 ft. of the dam moved off, three things would have occurred: (1) The 35-ft. upper part would have turned over, as it slid off of the lower part. This is disproved by the detached section, still standing, which did not turn over, and by the other section that was carried bodily down-stream, and which remained upright 40 minutes after the first break. (2) When the 35-ft. section moved down-stream, if by any miraculous intervention it could have slid off, then fallen a distance of 30 ft., and landed in the tail race in an upright position, its crest would have been 30 ft. below the crest of the standing portion. All this is disproved by the standing detached section. The crest of the standing section is only 4 ft. (instead of 30) lower than the original crest, and that of the portion which stood for awhile was as high, or higher, than the original crest. Four eye-witnesses of the failure unite in saying that one end of the latter section was a little higher than the other. This is what we might have expected from the topography of the tail race. The water in the tail race at this point was only 3 ft. deep; that is, the bottom of the tail race, at this point, was 5.5 ft. below "low water." From this point of the tail race to the power-house the bottom of the tail race was 9 ft., and even 12 ft., below the "low water" level. The section and one end, which stood for 40 minutes down-stream, rested in the tail race, where its depth was 5.5 ft., while the other end rested where the depth was 4 to 6 ft. lower. (3) The crest of the standing section is now 53 ft. above ordinary flow, where it would have been only about 22 ft. if the dam had broken at the 25-ft. level above "low water."

All the investigations made so far unite in confirming the view of Mr. H. M. Chance, expressed

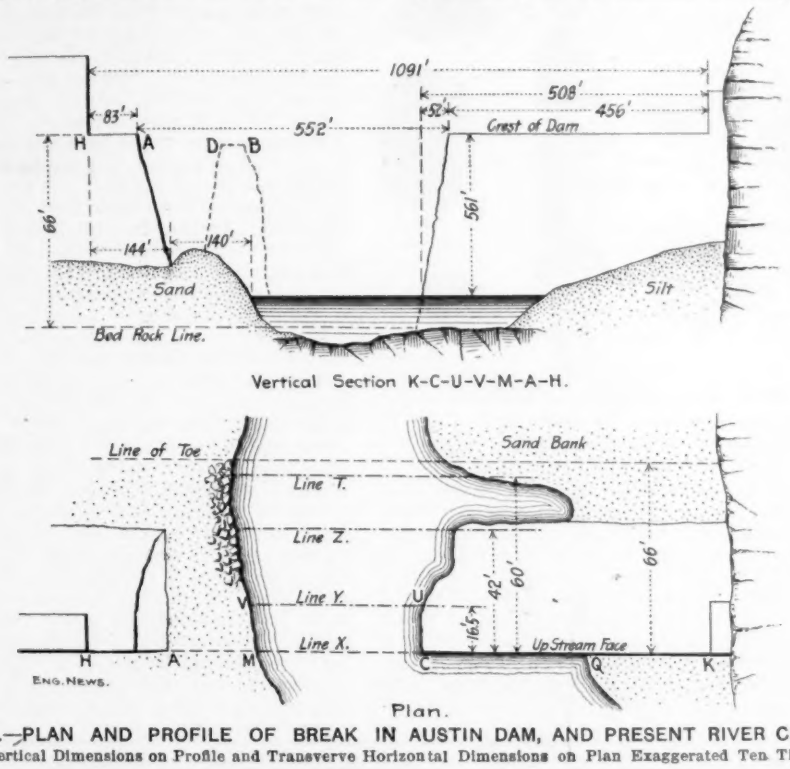


FIG. 1.—PLAN AND PROFILE OF BREAK IN AUSTIN DAM, AND PRESENT RIVER CHANNEL.
(Vertical Dimensions on Profile and Transverve Horizontal Dimensions on Plan Exaggerated Ten Times.)

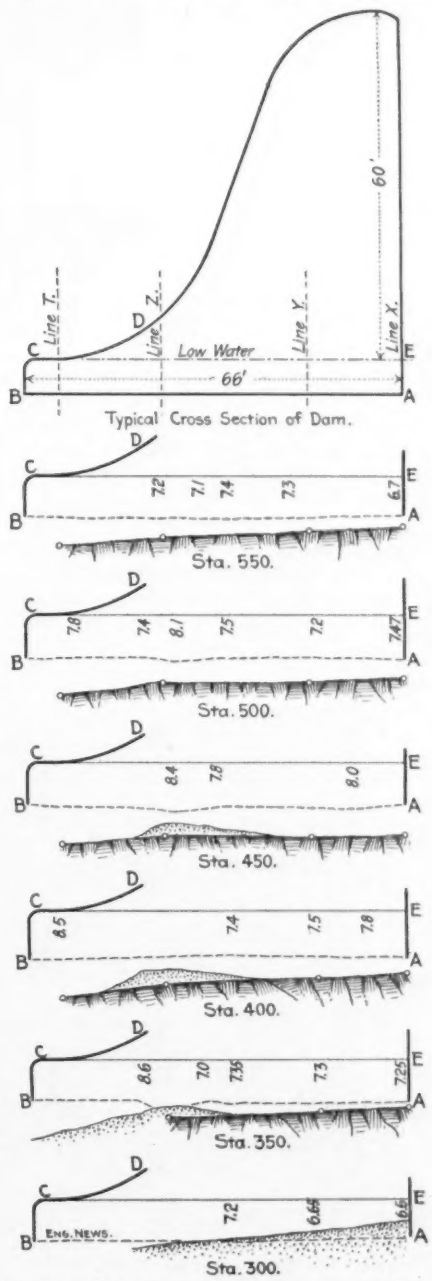


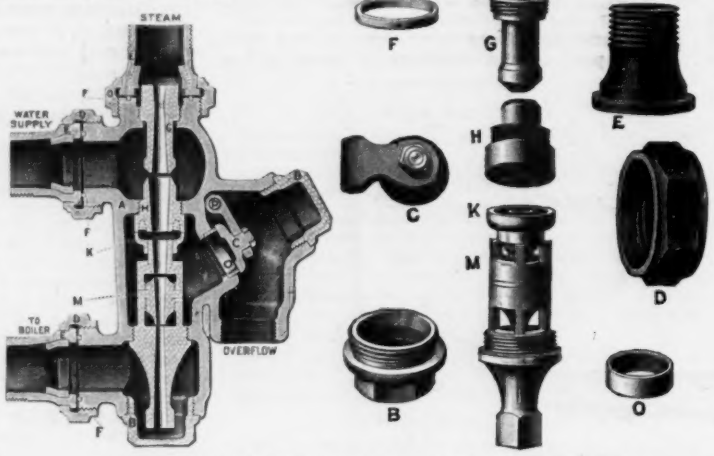
Fig. 2.—Original Cross-Sections of Foundation of Austin Dam and Profiles of Present River Bottom.
(Dotted Lines are Original Profiles; Shading Represents River Bottom.)

in the Engineering News of April 19, 1900,* that "the position of these fragments, horizontal and upright, appears to indicate that the cause of failure was a sliding-out bodily on its base of that portion that failed."

*For detailed accounts of the failure of the Austin dam, which occurred on April 7, 1900, and discussions of the cause of the failure, see Engineering News for April 12, 19 and 26, May 3 and 10, and June 14 and 21, 1900. The earliest of these references reviews the history of the dam and is accompanied by a long list of articles on its construction; its leaks, and the silting up of Lake McDonald, or the reservoir formed by the dam.—Ed.

A NEW AUTOMATIC INJECTOR.

The accompanying cut shows a cross-section and details of an injector for feeding stationary, marine or portable boilers, which has been just put on the market by the Lunkenheimer Co., of Cincinnati. In its general design it resembles the well-known "Penberthy" injector, but it has been planned with an especial aim to reduce wear, facilitate repairs and secure maximum range. The body of the injector is of cast iron, thus ensuring stiffness, and holding the tubes exactly in line. It sometimes happens with light brass body injectors that the strain of the pipe connections will badly spring the injector body. The various parts are screwed solidly to place and do not depend on pipe unions to secure them. The spillways are arranged in the connection pieces between the parts, and drilled spill-holes are thus eliminated. The overflow valve has a renewable disk resting against a renewable seat. The steam tube and the combining and delivery tube have each square end projections, so that they can be removed with any monkey wrench. We are informed that with steam pressures of 60 to 100 lbs., and water not more than 75°, the capacity of the injector can be varied more than one-half.



SECTION AND DETAILS OF AUTOMATIC INJECTOR.
Made by the Lunkenheimer Co., Cincinnati, O.
(Letters on Detail Parts Correspond to Those on the Sectional View.)

THE LAYING OUT OF TOWNS AND THE PLANNING OF A MODEL INDUSTRIAL CITY.

The industrial city which is proposed to be built near Waukegan, Ill., under the name of Zion City, by the organization styled the Christian Catholic Church, was referred to in our issue of Aug. 16, 1900. From an article by Mr. B. J. Ashley, the chief engineer, in a paper published by the organization, we take the general particulars given below as to the planning of this city. Before deciding upon any plan of procedure, Mr. Ashley sent out a circular of inquiry to the officials of a large number of cities of over 12,000 population. The questions in the circular were as follows:

(1) Width of street for residential purposes?
(2) Width of street for business purposes?
(3) Width of alley?
(4) Width and depth of lot for highest class residences?
(5) Width and depth of lot for middle class residences?
(6) Width and depth of lot for laboring class residences?
(7) Width and depth of lot for business purposes?
(8) Should sewers, water mains, etc., be placed in alleys or in streets?
(9) What are the two choice directions for the frontage of buildings?
(10) How high should floor or residence be from surface?
(11) What distance should middle class residences be from streets?
(12) Should tree planting be inside or outside of sidewalk?
(13) Distance between curbs on residential streets?
(14) Width of sidewalks on ordinary residential streets?
(15) What kind of pavements for residential streets?
(16) What kind of pavements for business streets?
(17) Should you advise municipal control of all tree planting?
(18) Would you contract out municipal improvements or do work by the day.

The answers to these questions have been tabulated by Mr. Ashley, and are presented in a recent number of "The Coming City," the paper mentioned above. Those interested in the detailed replies should write for a copy of the paper. Mr. Ashley's address is 1201 Michigan Ave., Chicago, Ill..

In Zion City the alleys will be 25 ft. wide, except those in which trunk sewers will run, which will be 35 ft. wide. The alleys in the manufacturing district are to be as wide as ordinary streets, for the reason that they will not only contain all the water and sewer pipes, telegraph and telephone lines, etc., but will have to accommodate from two to three railway tracks connecting with the factories. On these tracks cars will be loaded and unloaded. The depth of the lots will be normally 140 ft., with a minimum of 130 ft. and maximum of 180 ft., while on the boulevards the depth will be 200 ft. The width of frontage will be 40 ft. for the lots for the working classes, 50 to 80 ft. in the residence districts, and 100 ft. on the boulevards and central park or campus. These boulevard properties will have a building line of 75 ft., the minimum building line for all except business property will be 30 ft., while some of the more expensive lots will have the building line 40 ft. from the street. Nearly all the frontages are toward the east or west, so as to have plenty of sunlight. In the center of the city will be a square park of 200 acres, with a site for a temple. Other small parks will also be provided. From this park will radiate four boulevards 300 ft. wide, and another boulevard will extend along the top of the bluff west of the city. All buildings are to be of masonry.

The elevation of the main part of the city will be 11½ ft. above Lake Michigan. A complete system of sewerage and drainage for the entire area of 10 square miles has been planned, and at the home for the lace-workers there will be a small septic tank for sewage disposal. A drainage channel is being excavated. About four square miles of the territory have been laid off with section lines. A harbor is to be established having a depth of 20 ft. of water and two piers with an opening 300 ft. wide between them.

THE METROPOLITAN UNDERGROUND RAILWAY OF PARIS, FRANCE.

(With two-page plate.)

One of the most notable of the several improvements to the transit facilities of the City of Paris, which were planned in contemplation of the crowds that would have to be carried daily to and from the Exposition of 1900, was the construction of the section of the "Metropolitan Railway" running directly through the heart of Paris from the Porte de Vincennes to the Porte Maillot and the Porte Dauphine. This line was opened to traffic last July and has been in regular operation since. In its structural features the new Paris underground line differs generally from the older tunnel lines of London, and resembles quite closely our own Boston Subway, and the Rapid Transit Railway of New York city, now under construction. Another fact which will be noted is that the completed Paris underground line which is described here is only a small part of what will be when completed the most extensive system of underground railways of perhaps any city in the world. We have prepared the following description of the contemplated system and of the work already done from a paper by Mr. Raymond Godfernaux, printed in the "Revue Generale des Chemins de Fer," for September, 1900.

The project for an underground railway in Paris practically dates from 1883, when Mr. Haag presented a plan which has been developed into the system of lines now under construction and partially in operation. On Nov. 26, 1895, the government decided that a railway of this type was one of purely local interest and should be built as a municipal line for interior communication alone, and independently of the various railway systems abutting upon or serving the suburbs of the city. The law of March 30, 1898, authorized the City of Paris to construct the line and to concede to a company the operation of the system

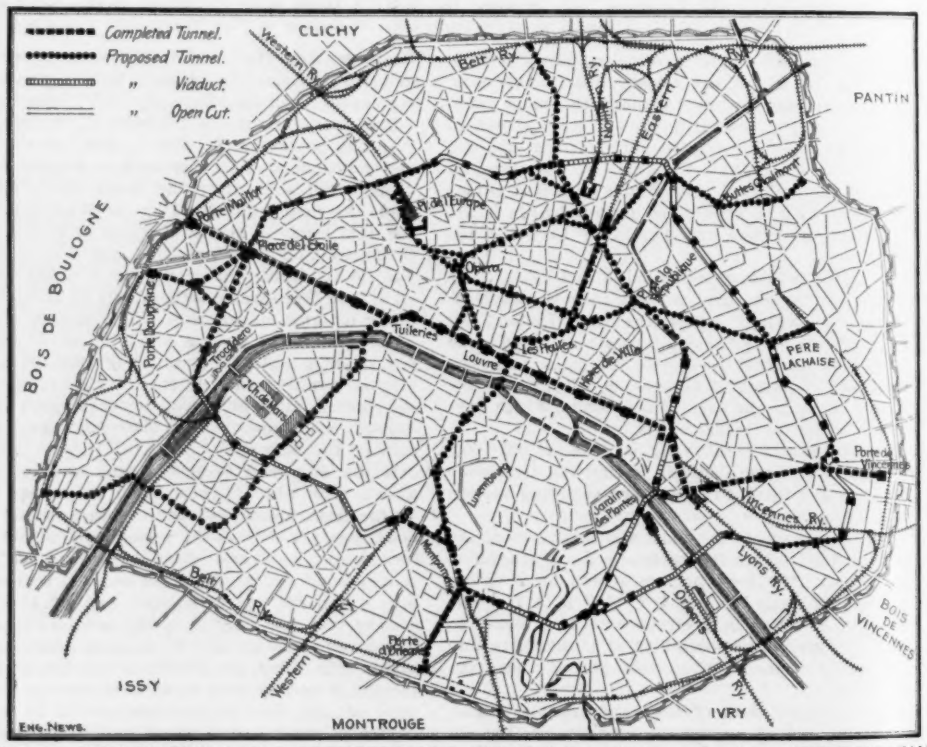


FIG. 1.—MAP SHOWING THE PROPOSED AND COMPLETED LINES OF THE METROPOLITAN RY. OF PARIS, FRANCE.

under stringent regulations. The route was laid down, as shown in the accompanying map, Fig. 1; the gage was fixed at 1.44 m., or 4 ft. 8⅝ ins.; the length of train was not to exceed 60 m., or 196.8 ft.; the speed was not to exceed 20 km., or 12.4 miles per hour; and the trains were to be operated by electricity. The time given for the complete execution of the work was 15 years from

the date of the law, and the lines laid down aggregated in length 64,697 m., or about 40 miles.

To meet the demands of the Exposition of 1900, and to fulfill promises made to the Ministers of Commerce, Industry and Posts and Telegraphs, it was decided to build first the cross line connecting the Porte de Vincennes with Porte Maillot and Porte Dauphine; a line which practically runs through the heart of Paris. As shown on the plan, Fig. 1, an angle is made to reach the station of the Lyons Railway; and at the Place de l'Etoile, three lines branch off; one leading to the Trocadero, one to Porte Dauphine, and one towards the north. The total length of the section thus ordered under construction was 8.7 miles. The radius of curve varied from 100 to 200 m., with a minimum adopted radius of 75 m., though conditions made it necessary to reduce this radius to 50 m. at the station at the Bastile, and at the Gare de Lyon.

The profile of this line practically follows the gradients of the streets under which it passes; the tunnel having the typical cross-section shown in Fig. 2, with the extrados of the arch about 3 ft. below the street surface. For single-track the section shown in Fig. 3 was adopted; and on curves of 50 m. radius the tunnel section had to be widened.

Owing to the necessity of placing the top of rails at the stations above the level of the water stratum found in the subsoil in the lower parts of the city, the stations were built in arched masonry when the water-level permitted, or with a metallic roof when the height was otherwise insufficient. Figs. 4 and 5 show these two types of construction. In the masonry roof the interior of the arch was covered with Portland cement mortar and the sides were lined with enamelled brick, or artificial stone. The dimensions of these several cross-sections are so fully given upon the drawings that they are not noted here.

The nature of the soil penetrated varied considerably. At the two ends, the material found under the pavement was sand, covered for a short distance north of the Place de l'Etoile with a thin bed of marl. This sand is slightly argillaceous, very dry and compact, and contained in some places nodules of hard sandstone. The maximum thickness of this sand stratum is about 8 m., or 26¼ ft.; it rests upon a marl formation passing into a rock. All of the natural soil, in fact, was of a favorable character for the execution of tunnel work, though ordinary precautions had, of course, to be taken. Under the greater part of the Rue de Rivoli, however, the presence of rubbish, frequently traversed by walls of old masonry rendered the excavation very difficult at some points In three places, also, it was necessary to place the work below the level of the prevailing ground water. The moving of the main sewer under a great part of the Rue de Rivoli, and the rebuilding of the galleries and conduits opening into it, cost 3,833,000 francs; and the relaying of water mains added 808,000 francs to this amount. Another item of preliminary expense was the construction of lateral galleries leading from the tunnel to points upon the Seine, where the excavated material could be loaded upon boats. Four of these laterals were built at a cost of 400,000 francs.

The tunnel excavation was commenced by the aid of shields, of the Berlier type, ordinarily used by French engineers; but it was soon found that progress by this means was too slow, and it became necessary to resort to open, timbered excavation of the ordinary type. The general plan followed was the so-called Belgian method of tunneling. The arch was first constructed, and the side walls were then put in by underpinning the arch. The earthen core was finally removed and the bottom arch, or invert, put in place. At the stations, however, the side walls were first constructed and the arch, or metallic roof built upen them; the earth from the core was then removed, as in a tunnel, and the invert was built last of all.

In all the masonry slow-setting mortar made of Portland cement was exclusively employed; though both gravel-beton and ordinary masonry were used in the work. The interior of the stations was lined with white tiles or enameled brick; and in the other parts of the tunnel a coating of quick-setting Vassy cement was applied to the arch, and Portland cement was used on the side walls and bottom arch.

The first sections of the Metropolitan line opened to traffic were completed in 17 working months. The actual cost of construction is given as follows:

	Francs.	Francs.
1—Construction	26,355,000	
Superintendence & contingencies.	4,145,000	
		30,500,000
2—Preparatory work:		
Galleries for removing debris...	400,000	
Changing sewers	3,841,000	
Changing water mains	800,000	
		5,041,000
3—Organization and personnel:		
Personnel and general expenses.	500,000	
Superintendence and inspecting..	900,000	
		1,400,000
Total cost		36,941,000

The cost per kilometer was thus 2,643,154 francs, or about $852,630 per mile. The cost of the work of construction alone was 1,888,000 francs per kilometer, or about $609,032 per mile. All of this work was performed at the cost of the City of Paris.

Under the law the operating company was required to provide access to the stations and to lay the track and furnish and lay all electrical conductors and their appliances. It also had to establish a central power plant, build the rolling stock, and equip the stations and the track for operation.

Access to the stations varied with the location, but the general plan followed was as follows: A stairway, commencing at the pavement level and surrounded by a guard rail, led to a subterranean gallery in which was placed the ticket office. These stairways were placed either at right angles to, or parallel with, the platforms; and a metal gallery crossed the tracks so as to permit access to either platform, as is shown in Figs. 6 and 7. Where a flat metal roof was used the arrangement at the stations followed the same general designs.

In the tracks, steel rails of the Vignoles type were used, weighing 52 kg. per m., or 104.4 lbs. per yd. The section of this rail, and its fastenings, is shown in Fig. 8. The rails were laid with alternating joints, and 16 ties were used to one rail-length of 49.2 ft., or 15 m. The ties were creosoted beechwood, and were 2.2 m. (7 ft. 2⅝ ins.) long, 0.14 m. (5½ ins.) high and 0.20 m. (7⅞ ins.) wide, except the joint ties, which were 0.30 m. (11 13-16 ins.) wide. At distances of 9.84 ft. apart a tie is put in 8 ft. 2⅝ ins. long, which serves to support the electric conductor, or the "third rail," shown in Fig. 9. This conductor weighs 78 lbs. per lin. yd., and is placed 13 ins. from the rail proper; it rests upon the tie on a tie-plate insulated by a sheet of "Hecla" insulator. The service rails take the return current, and for this purpose they are electrically connected at the joints by means of four copper conductors, as shown in Fig. 9. The ballast employed was gravel from the valley of the Seine, 2.6 cu. m. being used for every lineal meter of the tunnel; the ties project 1⅝ ins. above the surface of this ballast.

The power plant is located upon the Quai de la Rapie, and will furnish continuous current at 600 volts and triphase current at 5,000 volts and 25 periods. One part of the triphase current will be transformed at the station into a continuous current, and another part will feed a sub-station at the Place de l'Etoile, and will there be transformed according to the requirements of the service. The plant will include five groups of electric generators of a capacity of 1,500 K-W. each. One of these groups will produce the continuous current, and the other four the triphase current; they work in connection with a battery of Tudor accumulators of 1,500 ampere-hours. The power is furnished by five vertical compound engines of 2,600 I. HP., taking steam from 18 semi-tubular boilers with 4,270 sq. ft. of grate surface.

The cables conveying the electric current are placed in a special gallery leading under the Rue de Bercy and the Boulevard Didevot, and enter the tunnel at the Rue de Lyon. The cables for the continuous current are bare, and are united directly with the rails; the positive pole to the third rails and the negative pole to the service rails. The insulated cables carrying the triphase current rest upon the right-hand side of the tunnel invert. The sub-station at the Place de l'Etoile will contain the necessary transformers and converters, and also a battery of Tudor accumulators of 1,800 ampere-hours. The power necessary to operate the line actually constructed is estimated at about 3,000 K-W.; this will keep two of the groups of generators at work at the same time. It should be noted that as the Bercy power plant was not in operation when the Metropolitan Railway was opened to traffic, last July, power was temporarily furnished by the Parisian Compressed Air Co. and by the three-phase plant, recently erected at Asnieres.

The trains used are made up of one motor-car, to which are attached two or three ordinary cars, and the rolling stock now on hand includes 191 cars, of which 46 are motor-cars. The motor-cars are operated by two 100-HP. Westinghouse motors arranged for series-parallel control. The normal speed of the motor is 450 revolutions per minute. Each motor-car will pull three, and perhaps four, of the ordinary cars. All of the cars are provided with continuous Westinghouse brakes, and also with hand and electric brakes to be used in any emergency. They are lighted by ten electric lamps of 10 c. p. each. The general form of the car is shown in Fig. 10, each car seating 30 persons, and there is room for ten persons more standing. An indicator in each car, moved by the conductor of the train, shows the name of the next station ahead. The company believes it can reduce the stops to one-half minute, and thus make the run from the Porte de Vincennes to the Porte Maillot in one-half hour. During the daily period of greatest traffic the trains are to follow each other at two-minute intervals.

The tunnel is lighted by incandescent lamps of 16 c. p. each, placed on the arch a little above the

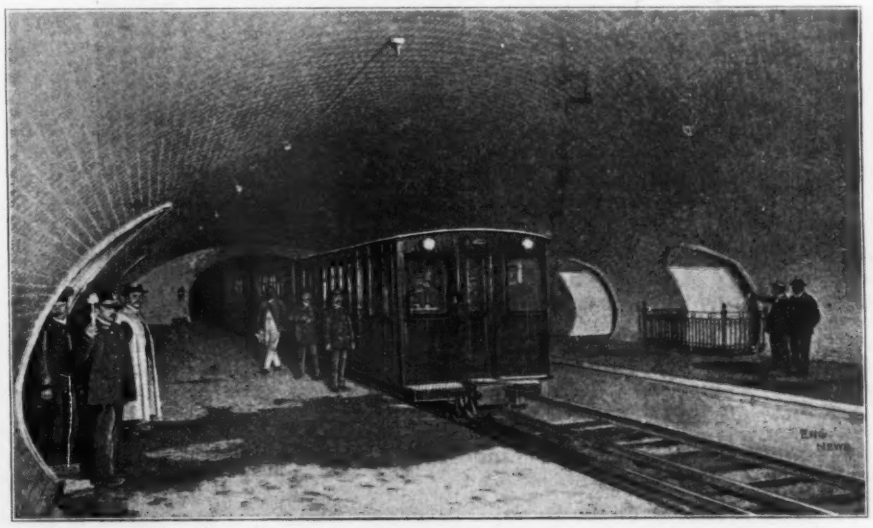


FIG. 13.—VIEW SHOWING TRAIN STANDING IN THE PLACE DE L'ETOILE STATION.

springing line; these lamps are set 41 ft. apart, for 246 ft. each side of a station, and 82 ft. apart at other points. The arched stations are lighted by two rows of 18 incandescent lamps of 16 c. p. each, located directly over each platform; in the stations with a metallic roof, where the diffusion of light is less, two rows of 28 incandescent lamps each are placed over the platforms, and these are reinforced by five arc lamps of 8 amperes each. The Hall block-signal system is used throughout, and each station is connected with the others and the power plant by telephones of the Dardeau type.

The contract made between the City of Paris and the General Traction Co., contains some peculiar clauses relating to labor. By the law of July 9, 1897, this company was obligated to organize, within six months, a company with not less than 25,000,000 francs capital, and with a board of direction made up exclusively of Frenchmen. The exclusive object of this company was to operate the Metropolitan railways, and the Traction Co. was to hand over to this operating company the concession granted to it on July 9, 1897, and it could not receive this concession without the express approval of the City of Paris. The appointment of the Manager of the operating company was to be approved by the city authorities, and the latter could demand his removal for cause. The operating company engaged itself to employ only French labor, and all material was to be of French manufacture, except where the City of Paris might specially authorize other material.

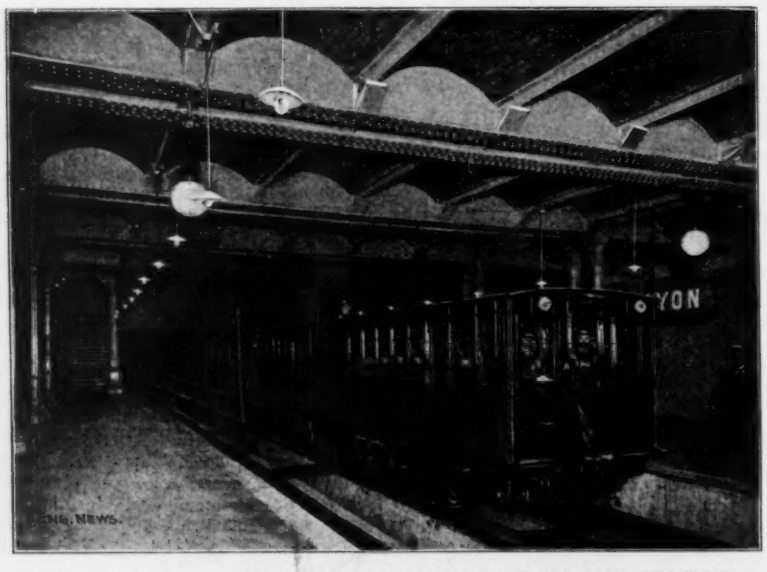


FIG. 14.—VIEW SHOWING TRAIN STANDING IN THE LYONS STATION.

The City of Paris, on its part, engaged to build the road; including all subterranean work, cuts and viaducts necessary for the establishment of the permanent way, and rebuild public ways where this is necessary. The city was also to build the platforms for passengers at the stations; but would not build the stairways to these station platforms. The operating company had to provide the permanent way and all its equipment and the station equipment, besides the rolling stock and power plant.

Under the head of labor the operating company was required to abide by the following regulations: All salaries were to be paid on the 15th of each month, and no one employed was to receive less than 150 francs ($30) per month; and temporary service was to be paid for at a minimum rate of 5 francs ($1.00) per day. The duration of a working day was not to exceed 10 hours; and one day or two half-days of rest were to be accorded to the personnel in each week. An annual holiday of 10 days was to be accorded to each man without loss of pay; and for days of sickness, not exceeding one month in one year, no pay was to be deducted. In case of accident resulting from the service the workman was to receive his whole salary until completely cured; without prejudice to any indemnity which would be due him in case he were finally, wholly or partially disabled. The workmen are also to be insured against accident at the expense of the operating company. And, further, whatever may be the imputation of responsibility for such accident, the company will always be directly responsible to the victim for the payment of an indemnity.

The operating company is also obliged to give to each workman a "livret," or book, showing that—out of a capital formed by retaining 2% of the salaries of the workmen, 6% of this amount is deposited in their name, under the following conditions: When the number of passengers exceeds 220,000,000 per year, the deduction from salaries is to be reduced to 1%, and the deposits made in the name of the workmen will bear 7% interest. Part of this agreement with the workmen is that the company must maintain a free medical and apothecary service, and insure all the workmen against accidents.

To enable the city to pay interest upon and to take up the bonds issued for the work of construction, it will receive from the operating company a profit on each ticket sold, as follows: With a traffic not exceeding 140,000,000 passengers per year, the city will receive 5 centimes out of each 15 centimes paid for a single 2d class ticket, and the same out of each return ticket costing 20 centimes; it will receive 10 centimes out of each 1st class ticket costing 25 centimes. When the traffic exceeds 140,000,000 passengers, each excess of 10,000,000 adds one-tenth centime to the above; but for all traffic above 190,000,000 the deductions cease to increase, and they remain thereafter fixed as follows: For a single 2nd class ticket, 5½ centimes; for a 2d class return ticket, the same, and for a 1st class ticket 10½ centimes. School children are to be carried for 5 centimes, and on this revenue the city makes no charge.

The law makes 35 the minimum number of trips each way per day; and each train must provide 100 places as a minimum. The train schedules will be fixed by the Prefect of Police with the assistance of the company, in such manner as best to serve the public and with an interruption of traffic of only four consecutive hours per day. No train shall exceed 236 ft. in length, and until the Prefect of Police shall otherwise authorize the speed is limited to 36 km., or 22.3 miles per hour.

The concession granted is to last for 35 years, the time dating from the completion of the several systems. Upon the expiration of this concession the City of Paris will be entitled to all the rights of the operating company, in its permanent ways and their appliances, and especially in the power plants for generating electric energy, and it will enter into immediate possession and enjoyment of all this property without indemnity. Further, during the five last years preceding the termination of the concession the city retains the right to seize the revenue of the system and to employ it in rebuilding the permanent way and all its dependencies, provided, that the operating company does not itself fully and satisfactorily meet all that is here implied by keeping the system in perfect order and repair. As to all private property, such as the rolling stock, station furniture, tools and machines in the workshops, etc., the city reserves the right to purchase this at a price fixed upon by experts appointed as agreed upon; but it is not compelled to purchase. The operating company is permitted to charge during the period of the concession, 25 centimes for 1st class, and 15 centimes for 2d class tickets for a continuous trip between any two points in the system. Children under 4 years of age, and held on the lap, are to be carried free; and the same holds good for any packages carried on the lap and not exceeding 22 lbs. in weight. Up to 9 a. m. passengers will be entitled to a round-trip ticket for 20 centimes, permitting them to return at any hour of the day. Pupils in the communal schools of Paris will only pay 5 centimes—when they travel in a party and in charge of a teacher. In any train the seats reserved for 1st class passengers must not exceed one-third of the capacity of the train; and 2d class passengers must be carried whenever there are seats of any class.

The station arrangement varies with the location; but the ordinary station has two platforms—one each side the line; each 75 m., or 246 ft. long, 4 m., or 13.12 ft. wide, and located 5.50 m., or 18.04 ft. apart, across the tracks. The terminal stations are provided with loops, as shown in Fig. 11, and the station at the Place de l'Etoile required a special disposition (see Fig. 12), as two branch lines depart from this point. As shown by Fig. 12, the Trocadero branch terminates in a loop passing around the Arc de Triomphe, and has its station connected with the one on the Vincennes-Maillot line, but independent of it. They are on the same level, and stairways connect the street with the four station platforms. The two systems of railway are connected under the Avenue Friedland; while a single-track line completes the circle of the loop. The branch line to the Porte Dauphine passes under the lines first mentioned, and has its station on the Avenue Wagram. This latter will also serve as a station for the proposed prolongation of this line to the outer boulevards; a single track line connects this branch with the line leading to the Porte Maillot.

REMINISCENCES OF EARLY HIGH-SPEED STEAM ENGINEERING.*

By Charles T. Porter, Hon. M. Am. Soc. M. E.†

This meeting following close upon the death of John F. Allen, seems a fit occasion to give to the Society some reminiscences of Mr. Allen, and of the infancy of high-speed steam engineering.

One morning in the winter of 1860-61, Mr. Henry A. Huribut, then of Swift, Huribut & Co., wholesale dealers in hats, at No. 65 Broadway, and who had become interested in my governor manufacture, called upon me to tell me that a friend of his, Mr. Henry A. Burr, manufacturer of felt-hat bodies, at the corner of Frankfort and Cliff Sts., in New York, had been having trouble with his engine. He thought my governor was just what he needed and asked me to accompany him to Mr. Burr's office, where he would give me the advantage of his personal introduction. In the interview with Mr. Burr which followed, I did not have an opportunity to say a word. After Mr. Huribut had explained the object of our visit, Mr. Burr replied that he had had a great deal of trouble with the regulation of his engine, and had thought seriously of getting a Corliss engine in the place of it; but, two or three weeks before, the builders of the engine had sent him a very skilful engineer, and since he came there had been no further trouble, so he should not need my governor.

He invited us to see his engine, in which—since it had been taught to behave itself—he evidently took much pride. We found a pair of beam engines of about 5 ft. stroke, running at 25 revolutions per minute, made by Thurston & Gardiner, of Providence. They had the usual poppet valves and the Sickles cut-off. This was made adjustable, and was regulated by the governor. At the time of our entrance, Mr. Allen, the new engineer, was on the scaffold, lubricating the beam centers. Mr. Burr called him and he same down, and at Mr. Burr's request explained to us the liberating mechanism and what he had done to make it work satisfactorily. The regulation did not appear to me to be very close, and I made a determined effort to induce Mr. Burr to substitute one of my

*From a paper presented at the New York meeting of the American Society of Mechanical Engineers.

†39 South Fullerton Ave., Montclair, N. J.

governors. I showed him a cut of the governor, and pointed out its combination of power and sensitiveness, but all in vain. He was satisfied with things as they were, and I went away crestfallen, having lost not only the sale of a governor, but also an opportunity for a triumph in a very important place.

But I did not know to whom I had in fact been talking. As we were leaving, Mr. Allen asked me if I would call some time and see him—he had something he thought I would be interested in. I called soon after. He told me he had a plan for a variable cut-off, with positive movements, which he thought would avoid objections to the liberating gear. He had had it in his mind a good while, but did not think it could be used, because the governor could not handle the block in his link so as to maintain steady motion, and he had been inclined to abandon the idea; but when he heard me describing my governor to Mr. Burr it occurred to him that that governor would do, and he would like to explain it to me. He had no drawing, not a line; the design existed only in his mind. He put down his ideas, as he fitly expressed it, with chalk on the engine-room floor, and that rude sketch represented the perfectly matured system.

When his plan came to be analyzed, it was found that everything had been thought out and provided for, even to equalizing the opposite port openings, and compensating for the unequal piston motion produced by the vibration of the connecting-rod, so as to make the opposite diagrams identical. But the wonder did not stop there. Mr. Allen had remedied the defect in the link motion of making a narrow opening for admission when cutting off early, by employing a four-opening admission-valve of unique design at each end of the cylinder, and also by greatly enlarging these openings.

The four-opening valve required four seats in one plane, and it was important that these should be as narrow as possible. For this purpose Mr. Allen employed the Corliss wrist-plate movement to reduce the lap of the valve and, by an elegant improvement on this movement, he made it available also to enlarge the openings. This improvement consisted in the employment of two rockers having a common axis, and separate driving-arms, as well as driven-arms, for each valve. The driving-arms were made to vibrate a long way towards their dead points, and the increased opening movement in arc thus obtained was imparted directly to the valve. This combination of an enlarged opening with a reduced lap was, perhaps, the most surprising feature of Mr. Allen's system.

The four-opening equilibrium valve, soon afterwards invented by Mr. Allen, required but two seats in one plane. The seats could, therefore, be made wider. For the sake of simplicity, this division was then dispensed with, and the same enlarged openings were obtained by increasing the length of the driven-arms, submitting to the increased motion on the lap. That this remarkable system of parts and movements should have been elaborated in the mind of a man who had no knowledge of mechanics, except what he had absorbed in engine rooms, must stand among the marvels of inventive power.

After Mr. Allen had explained his plan to me, I expressed my confidence that my governor would meet its requirements, and observed that it would enable a variable cut-off engine to be run as fast as a locomotive. Somewhat to my surprise, he replied that he wanted his cut-off compared with the liberating cut-off turn for turn; that it had an advantage which he thought would cause it to be generally preferred at the same speed. I was then ignorant of his state of mind on that subject, or of what had produced it. I learned these afterwards, and will state them here. In one of our interviews, in reply to my question concerning what had led him to make this invention, he told me it was his experience when he was engineer of the propeller "Curlew," a freight boat running on Long Island Sound, between New York and Providence, which had a Corliss engine. He became impressed with what he thought to be a serious defect in the liberating system. The governor did not control the point of cut-off, but the point of release; this point being at the beginning of the closing movement of the valve, while the cut-off took place at the end of that movement. When the engine was worked up to nearly its capacity, as was the case in a ship, the port was opened wide, and quite an appreciable time elapsed between the release and the cut-off. During this interval, the piston advanced considerably, and if the engine ran fast enough, it might get to the very end of the stroke. He said in smooth water they had no trouble, but in the open ocean going around Point Judith, it was always rough, and sometimes in stormy weather the screw would be thrown quite out of the water, and the engine, having no fly-wheel, would race most furiously. The faster it ran, the further the steam would follow, and was pumped out of the boiler very rapidly. Springs were employed to accelerate the closing movement of the valves, but in these cases they seemed to be of little use, and were continually breaking. He saw that this difficulty could be avoided only by a positive motion gear which would enable the governor to control the point of cut-off itself; and, accordingly, he set himself to work to devise such a system. We know now that this judgment, formed from observations made under very exceptional conditions, was not well founded. The difficulty in question does not practically exist in engines having fly-wheels and the present improved liberating gear; but the experience naturally made a deep impression upon Mr. Allen's mind, and led to the invention of the positive motion system.

This he did not tell me at the time, so that I was at a loss to understand his reluctance to admit what was really the great value of his invention. However, I told him I would be willing to attempt its introduction, provided he would allow me to apply it at once to a high-speed engine; that being a field into which the liberating system could not enter. To this he assented, and I took him directly to the office of Mr. Charles B. Richards, now Professor of Mechanical Engineering in the Sheffield Scientific School of Yale University, who then had an office on Nassau St., where he was doing business as a mechanical expert and designer of machinery, and who had done some excellent work for me. I engaged Mr. Richards to make an analysis and drawing of Mr. Allen's system under his direction, and soon afterwards gave him an order for the plans for an experimental engine 6 × 15 ins., to make 160 revolutions per minute.

The subject of an indicator directly presented itself. Mr. Allen invited Mr. Richards and myself to his engine-room, and took diagrams for us with a McNaught indicator. This was the first indicator that either of us had ever seen. Indicators were then but little known in this country. The Novelty Iron Works made a very few McNaught indicators, almost the only users of which were the Navy Department and a few men like Ericsson, Stevens, Sickles and Corliss. I told Mr. Richards that we must have a high-speed indicator, and he was just the man to get it up for us. He went to work at it, but soon became quite discouraged. He could not see his way. I told him I was not able to make any suggestion, but the indicator we must have, and he had to produce it. After some months he handed me a drawing of an indicator which has never been changed, except in a few details. This important invention, which has made high-speed engineering possible, came from the hands of Mr. Richards quite perfect. Its main features, as is well known, are a short piston motion against a short, stiff spring; light multiplying levers, with a Watts parallel motion, giving to the pencil very nearly a straight line of movement; and a free rotative motion of the pencil connections around the axis of the piston, which itself is capable of only the slight rotation caused by the compression or elongation of the spring. Elegant improvements have since been made, adapting the indicator to still higher engine speeds; but these have consisted only in advancing further on the lines struck out by Mr. Richards. In fact, this was all that could be done—giving to the piston a little less motion, lightening still further the pencil movement, and making the line drawn by the pencil more nearly a straight line.

I took Mr. Richards's drawing to the Novelty Iron Works and had an indicator ready for use when the engine was completed. The engine was made by the firm of McLaren & Anderson on Horatio St., New York. It was set up by the side of their throttle-valve engine, and was substituted for it to drive their own machinery and that of a kindling wood-yard adjoining for which they furnished the power. It ran perfectly from the start, and saved one-half of the fuel. In throttle-valve engines in those days the ports and pipes were generally so small that only a part of the boiler pressure was realized in the cylinder, and that part was hard to get out, and nobody knew what either this pressure or the back pressure was. A diagram taken from that engine is here reproduced.

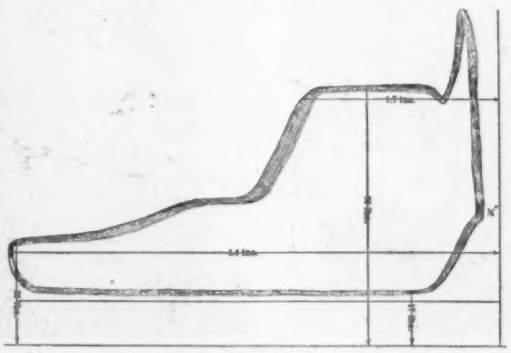


Diagram Taken September 13, 1861, From the First Allen Engine by the First Richards Indicator.
(Engine, 6 × 15 ins., making 160 revolutions per minute. This card was run over 20 times.)

The success of this engine was such that I determined to build a larger engine for the approaching London Exhibition of 1862, and the next May found an Allen engine, 8 × 24 ins., making 150 revolutions per minute, in operation in that exhibition, with a success which is a matter of history. There were 24 engines in the exhibition, mostly English, all small and all non-condensing, as no water for condensing purposes was obtainable in the locality. That, however, did not strike me as odd, for I had never seen a condensing engine in any public exhibition. They were all quite inferior, what the English would call "a rum lot." A large battery of boilers was unable to maintain the steam pressure, which had been fixed at 70 lbs. per sq. in. Especially when the Gwynne centrifugal pump was running the pressure always fell a pound a minute, so that it never was allowed to run over 15 minutes at a time. Mr. Allen came over in the fall, and soon after his return he sent me a drawing of his equilibrium four-opening valve and adjustable pressure-plate, which completed his design, according to which the engines have since been made.

The year 1863 was devoted by me partly to the introduction of the indicator and partly to the revision of the engine plans, including the introduction of the equilibrium valves. Among others things, I designed the present engine bed.* The manufacture of the engine in England, according to thes revised plans, was commenced in January, 1864, by the firm of Ormerod, Grierson & Co., of Manchester. In the year 1866 this firm failed, and on the invitation of the Whitworth Company I transferred the business to them.

The Whitworth Company sent to the Paris Exposition of 1867 four Allen engines, and also a sectional model, the latter being a complete small engine with the upper half of the cylinder and steam chest planed off, showing the valves in section, all being exhibited in slow motion. Three of the engines were 6 × 12 ins. Two of these were employed to drive an electric apparatus for the British Lighthouse Board, and were run at 300 revolutions per minute. The third was run idle at 500 revolutions per minute, to illustrate the adaptation of Mr. Allen's system to very high speed. For this illustration careful preparations were made. The fly-wheel was a light solid disk, 2 ft. in diameter. The reciprocating parts weighed only 40 lbs., and were exactly balanced by the counter-weight. The bed was filled with lead. The whole was set on a single block of Caen stone 3 ft. thick. This engine was shown for one or two minutes several times a day, at its top speed by holding up the end of the governor lever, so bringing the block to the top of the link and letting it hum. It ran, as nearly as could be judged, at over 2,000 revolutions per minute. When the governor resumed control and the speed slowed down to 500 revolutions, it always seemed to the bystanders as if the engine were going to stop. The fourth engine was 12 × 24 ins., making 200 revolutions per minute, and driving a portion of the English machinery exhibit. This was a condensing engine.

At the London Exhibition of 1862, one of the first questions asked me, and which I heard often afterwards, was: "How do you drive your air-pump?" The form of the question, it will be observed, assumed that, of course, the engine had an air-pump, which it was understood could not be used there. At first, I innocently replied that the engine was a non-condensing engine, and had no air-pump, little aware of the effect this answer had on the mind of the questioner. After a while I became by degrees conscious that I was among conditions and habits of thought very different from those to which I had been accustomed. The fact was, that, from an engineering point of view, to the English mind a non-condensing engine was no engine at all. They were always simple and cheap engines, built mostly for export—commercial goods only. All engines of the least consequence in England were condensing engines, and as my engine claimed to be at least respectable, it must have an air-pump, of course. As my destitution in this respect became known, I came perilously near to being dropped, and never knowing why.

Easton, Amos & Sons frankly expressed to me the concensus of engineering opinion, that high speed, while successful in non-condensing engines, was not to be thought of for condensing engines. In the then existing state of the art, this condemnation was unavoidable. The air-pump must run with the engine, stroke for stroke. At high speed it would lose its efficiency for two reasons. The valves would not seat themselves in time, and the air and water would be churned into foam. The question with which I had become so familiar, slightly changed to the form "How are you going to drive your air-pump?" was before me, imperatively demanding an answer.

I wrestled with this problem all the while I was with Ormerod, Grierson & Co., and when I went to the Whitworth Company, had a design ready to be put in execution.

This condenser was planned on a somewhat new constructive principle. It was a square box, set behind the engine and divided into three compartments, one occupying the lower and two the upper half. One of these latter was the condenser and the other the hot-well. The bottom of the condenser was inclined slightly downward from the hot-well. The valves were large, with a short lift and were closed by springs.

In the lower chamber was a single acting ram, connected with an extension of the piston-rod, and working in a body of water. It was hollow, floating in the water, and pointed so as to move through without disturbing it. The areas were such that a motion of the ram of one foot produced a rise or subsidence of the water of 1 in. The air, it will be observed, remained above the water, was drawn in last and expelled first. There was no place where a particle of air could be trapped.

It being evident that this condenser would answer, I put

*This bed was adopted by Tangye Brothers, of Birmingham, several years afterwards.

three of them in hand at once, for three engines to be run at 150 revolutions per minute, and, there being no alternative, I sent the first one that was ready to Paris, to be tested in the Exposition; and moreover, determined to settle the question decisively as to the adaptation of high speed for condensing engines, I put the speed of that engine up to 200 revolutions per minute, and I had the best vacuum in the Exposition, where several condensing engines were shown, some very large. The gage stood always between 28 and 29 ins. This condenser was not patented. Twenty-five years after I learned that it had come into general use in Europe.

I received three propositions from French builders. The first two, made nearly simultaneously in the summer, were both accepted in the autumn, the parties agreeing to work together. I was sorry when this obliged me to decline an application, which came just before the close of the Exposition, expressed in the most complimentary terms, from Farcot et Cie., the leading builders of stationary engines in France, and the largest exhibitors of them at the Exposition, after they had observed the running of the engine for nearly seven months.

In 1871 Mr. Allen, as is often the case with genius, longing for new worlds to conquer, sold out his interest in the engine business, and devoted himself thereafter to the development of the pneumatic riveter and the air-compressor.

In my intercourse with Mr. Allen I was always impressed with the depth of his penetration, and the general soundness of his judgment. He lived in a region of engineering and mechanical principles, with which his familiarity was certainly intuitive. Deprived of all early advantages, the world gave him nothing, but he will be counted among those who have given much to the world.

PNEUMATIC FIELD RIVETING OUTFIT OF THE KEYSTONE BRIDGE WORKS.

In our issue of Oct. 18, 1900, we published in abstract the report of the Committee of the Association of Railway Superintendents of Bridges and Buildings, on the use of pneumatic riveting outfits for railway bridge field work. This report described in some detail the pneumatic riveting outfits used on the Missouri, Kansas & Texas, the Southern Pacific and the Illinois Central railways, and gave some unusually interesting records of the economy and efficiency of these outfits as compared with field riveting by hand. In the accompanying cuts we show the general character and arrangement of the pneumatic field riveting outfit of the Keystone Bridge Works of the Carnegie Steel Co., of Pittsburg, Pa. This plant was designed by Mr. W. A. Cline, Superintendent of Erection of the Keystone Bridge Works, for use in the construction and erection work of that establishment.

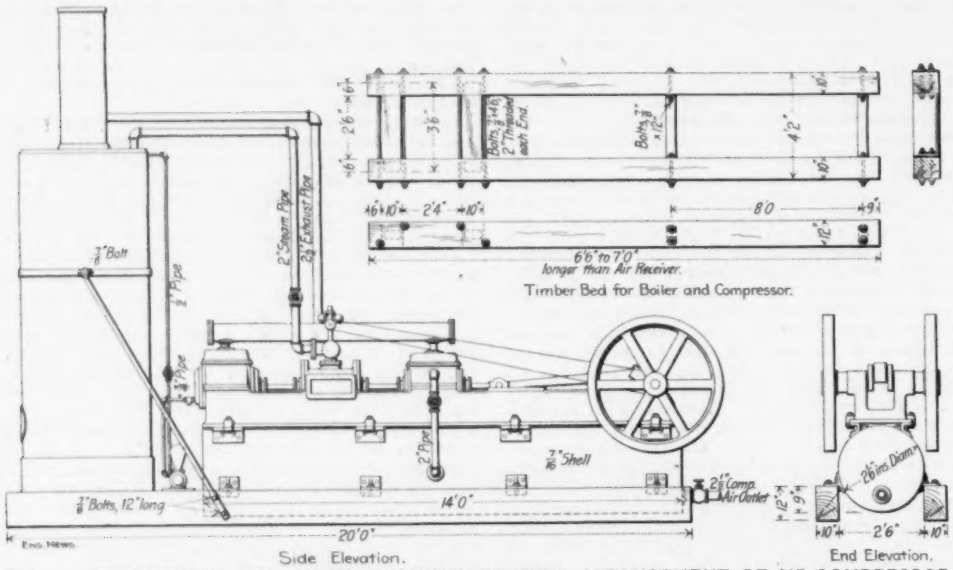


FIG. 1.—ELEVATIONS AND PLAN SHOWING GENERAL ARRANGEMENT OF AIR-COMPRESSOR PLANT FOR PNEUMATIC FIELD RIVETING.
Keystone Bridge Works, Pittsburg, Pa.

The receiver and compressor are combined in such a shape that the plant can be readily placed on viaduct or bridge work and not interfere with the passing of trains. The compressor can be run by any ordinary hoisting boiler of 20 HP. capacity or more. At the present time the plant is running six pneumatic riveting hammers, furnishing the air to heat the rivets and drilling 2-in. holes in 1½-in. material with a Monitor air drill. The outfit was first used in the erection of the open-hearth furnaces at the Duquesne steel works of the Carnegie Steel Co., and is now being used on the Rankin bridge, crossing the Monongahela river, for the Union Railroad Co. The compressor and air receiver were built by the Hall Steam Pump Co., of Pittsburg, after plans furnished by the Keystone Bridge Works.

The steam exhausted from the compressor is carried to the smokestack and is utilized for increasing the draft, as on any ordinary hoisting engine. The boiler is set at present on the end of a pair of 20-ft. timber sills, spaced 2 ft. 6 ins. apart. These sills also serve as a bed for the horizontal air receiver, which, in turn, is the bed for the air compressor, having cast-iron brackets riveted to the receiver at both top and bottom to support the compressor frame. The receiver is 30 ins. in diameter and 14 ft. long, made from 7-16-in. thick steel boiler plate, all longitudinal seams being double riveted. It is stated that the builders made objections to placing the air compressor on top of the receiver, but experience has shown that their fears were groundless. Mr. Cline recommended the arrangement to save space and for convenience in moving.

The dimensions of the complete machine are 20 ft. × 4 ft. × 12 ft. high, from bottom of sills to top of boiler. The compressor and receiver alone could be placed on a car and only occupy 4 ft. in width, 16 ft. in length and 7 ft. 6 ins. in height.

The compressor is a tandem two-stage machine with 10-in. steam cylinder, 10-in. low-pressure and 6-in. high-pressure air cylinders, all having 14-in stroke. Each air cylinder is jacketed for the circulation of water in body, heads and valve caps. Between the cylinders is an inter-cooler for reducing the temperature of the air after its first compression and before entering the 6-in. cylinder. The speed is controlled by a governor and automatic pressure regulator. With a boiler pressure of 70 lbs., the air pressure in the receiver is kept at 105 lbs., the compressor running from 50 to 60 revolutions per minute.

The main features aimed at in the design of the machine were to adopt its size to the work; to use slow speed so that the machine could be run by any ordinary engineer, and to secure air pressure sufficient to do good work on the heaviest rivets with a moderate steam pressure. In tests of the machine the air pressure has been run up to 140 lbs. with only 95 lbs. steam pressure.

The accompanying drawing, Fig. 1, gives the general details of the machine, and some of the principal dimensions. The small pump shown in the elevation between the receiver and boiler is used when no other water pressure is available for keeping up the water circulation around the cylinders and inter-cooler. The views, Figs. 2 and 3, were taken at the Rankin Bridge and show the machine in working order.

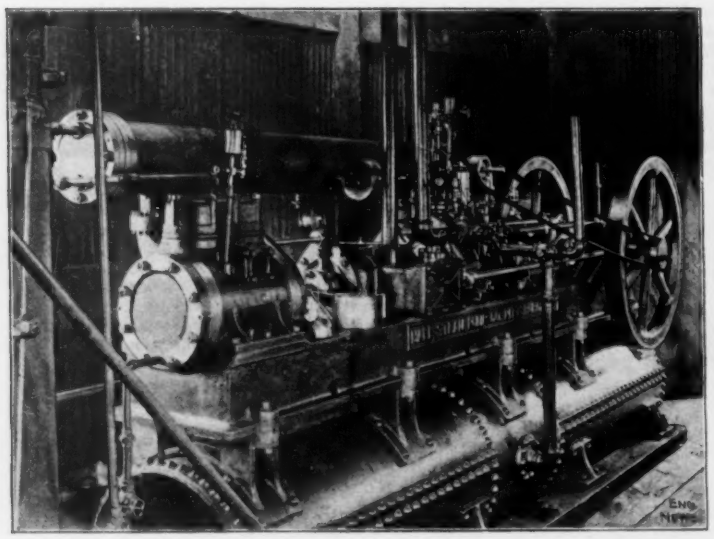


FIG. 2.—VIEW SHOWING MANNER OF MOUNTING COMPRESSOR ON THE RECEIVER.

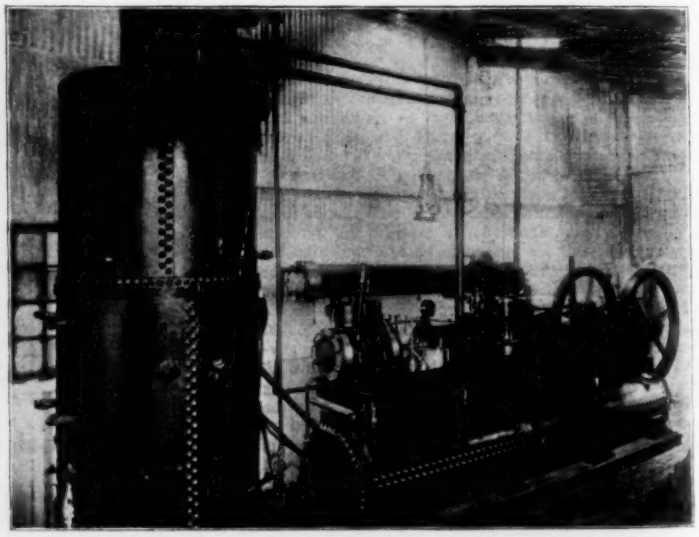


FIG. 3.—VIEW SHOWING BOILER AND STEAM CONNECTIONS TO THE AIR COMPRESSOR.

FIGS. 2 AND 3.—AIR-COMPRESSOR PLANT FOR PNEUMATIC FIELD RIVETING; RANKIN BRIDGE, PITTSBURG, PA.

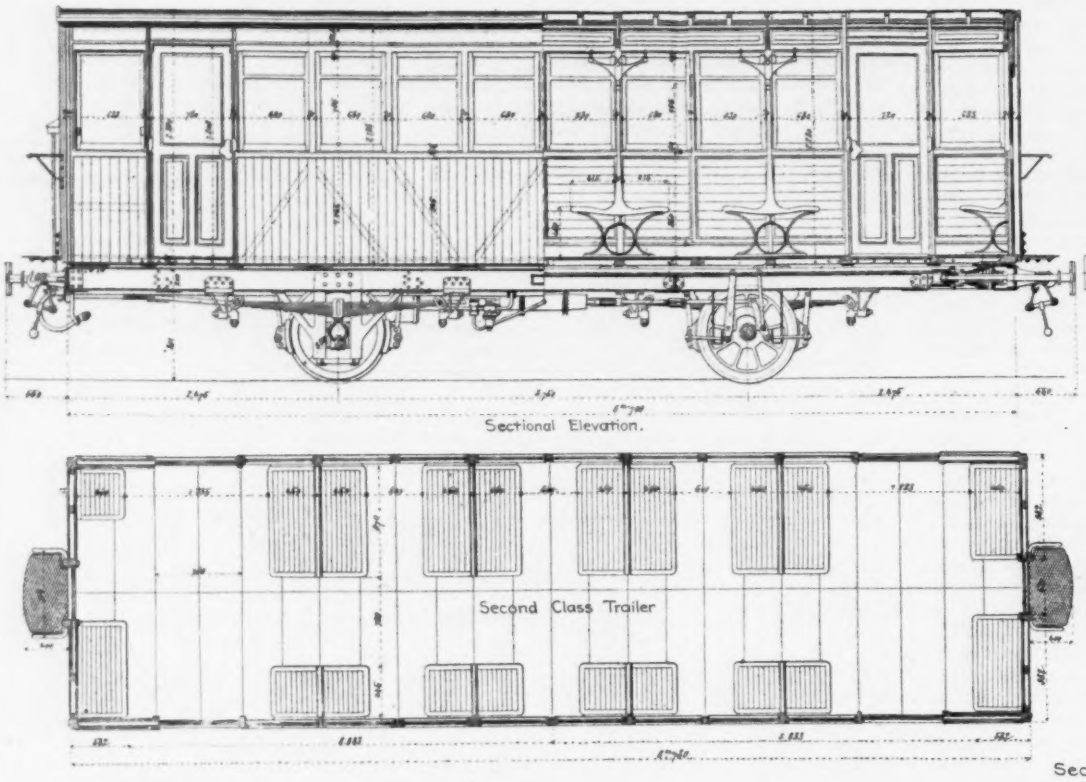


FIG. 10.—SECTIONAL ELEVATIONS AND PLANS OF MOTOR CARS AND TRAILERS.

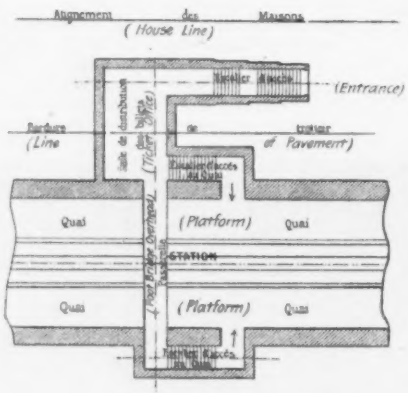


Fig. 6. Horizontal Section.

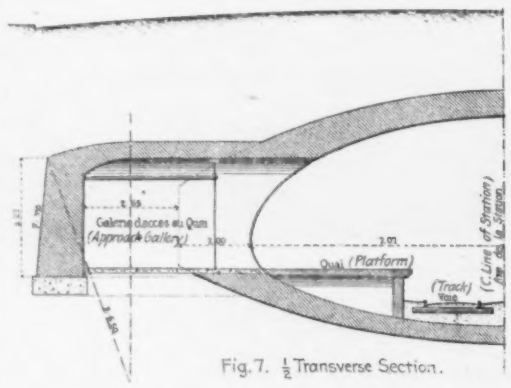


Fig. 7. ½ Transverse Section.

FIGS. 6 AND 7.—PLAN AND SECTION OF STATION, SHOWING STAIRWAYS AND OVERHEAD FOOT BRIDGE.

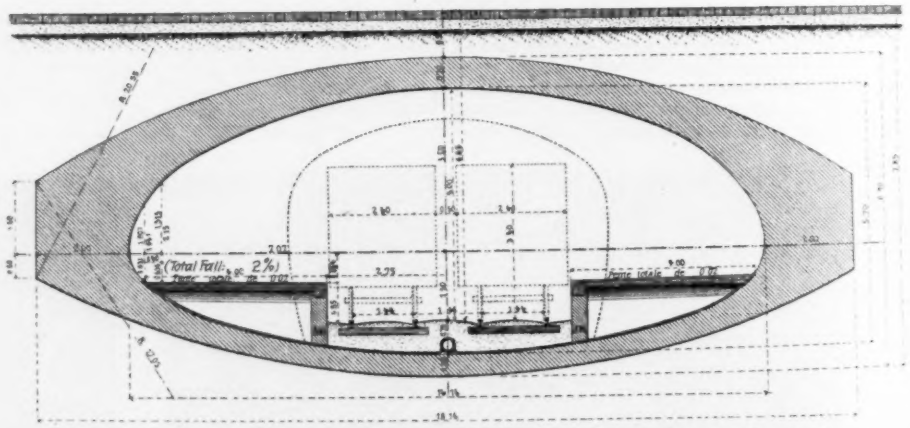


FIG. 4.—TRANSVERSE SECTION OF STATION WITH MASONRY ARCH ROOF.

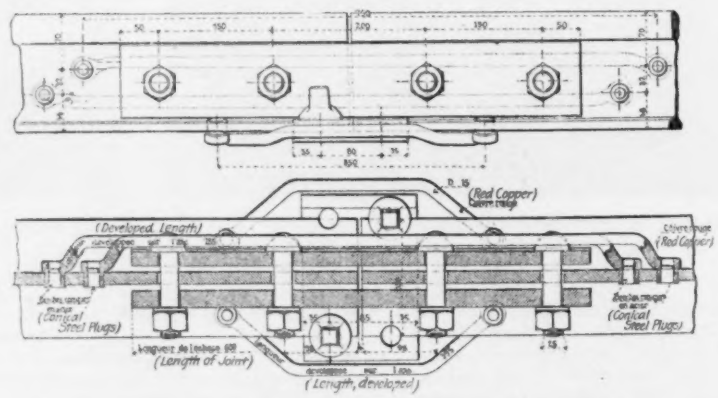


FIG. 9.—RAIL JOINT AND ELECTRIC CONNECTIONS.

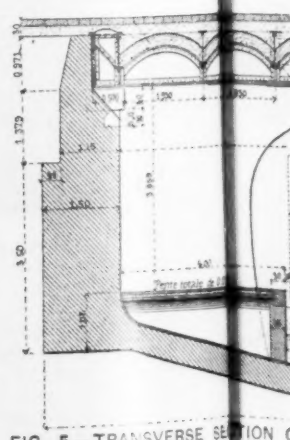
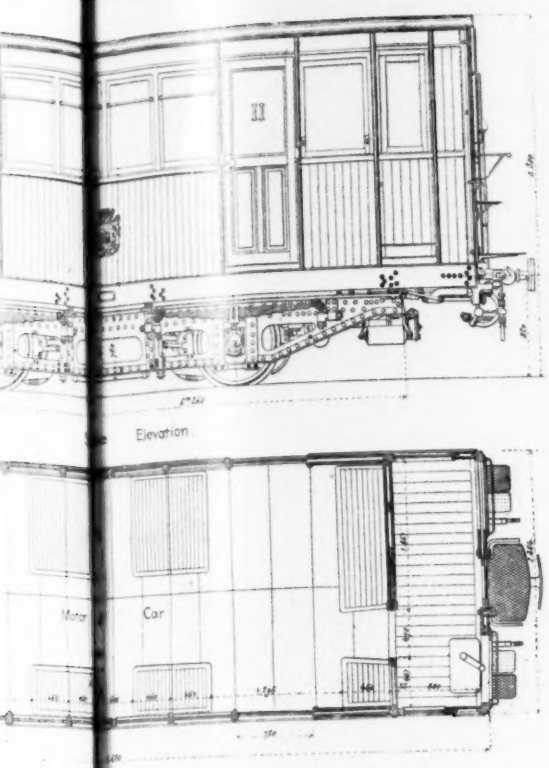


FIG. 5.—TRANSVERSE SE

THE METROPOLITAN UNDERGROUND

CARS AND TRAILERS.



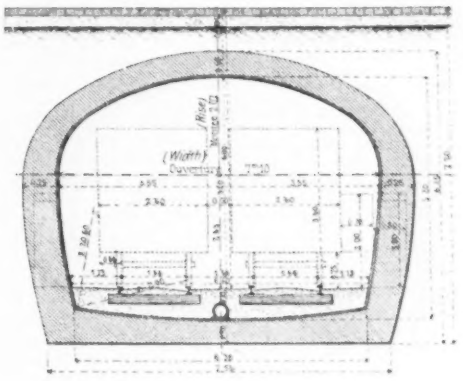


FIG. 2.
SECTION OF DOUBLE TRACK
TUNNEL LINE.

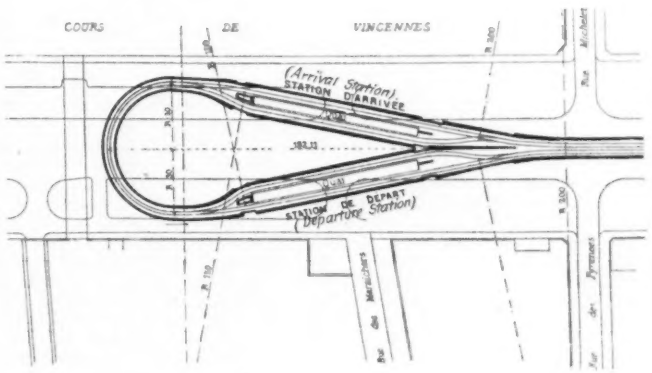


FIG. 11.—TERMINAL STATION LOOP AT VINCENNES.

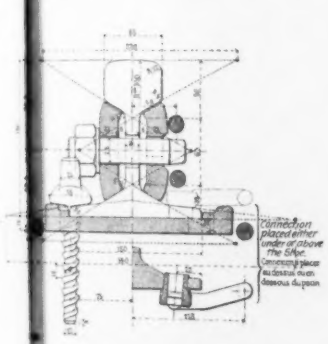


FIG. 8.—SECTION OF
SERVICE RAIL AND
JOINT FASTENING.

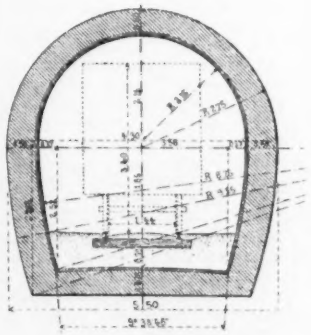
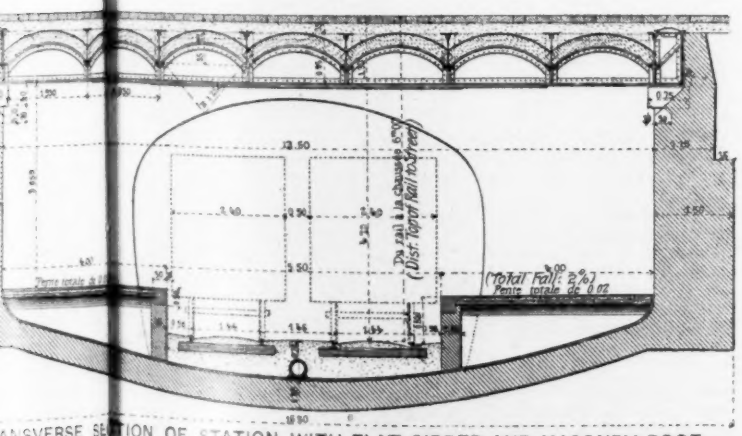


FIG. 3.—SECTION OF
SINGLE TRACK CONNECTING
TUNNEL LINE.



ANSVERSE SECTION OF STATION WITH FLAT GIRDER AND MASONRY ROOF.

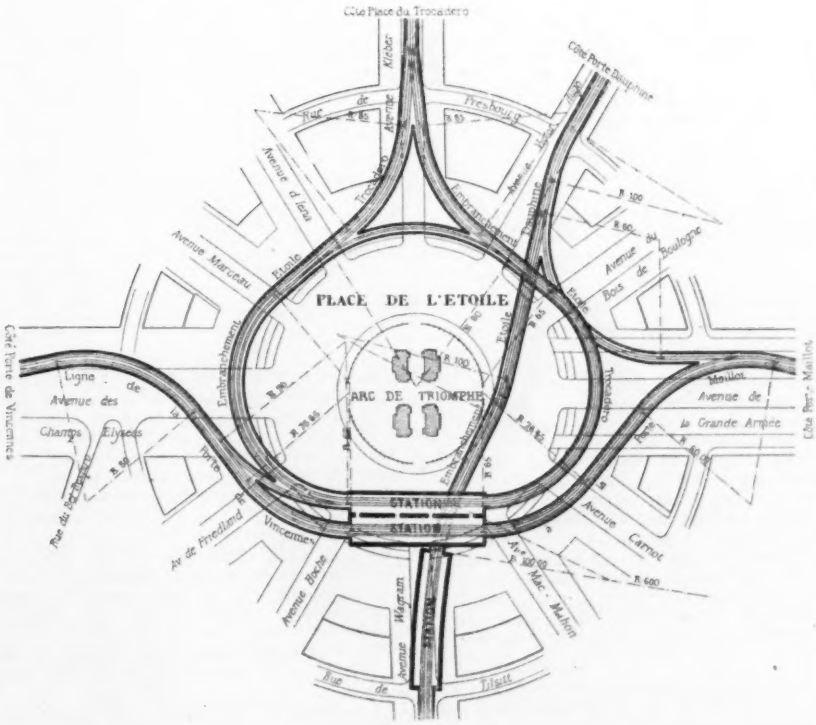


FIG. 12.—TERMINAL STATIONS AND LOOP LINES AT THE PLACE DE L'ETOILE.

UNDERGROUND RAILWAY, PARIS, FRANCE.